

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

DRA

Prepared for the
National Aeronautics and Space Administration

FINAL REPORT

(NASA-CR-149189) RED RIVER CHLORIDE REMOTE
SENSING STUDY Final Report (Army Engineer
District, Tulsa, Okla.) 44 p HC A03/MF A01
CSSL 08H

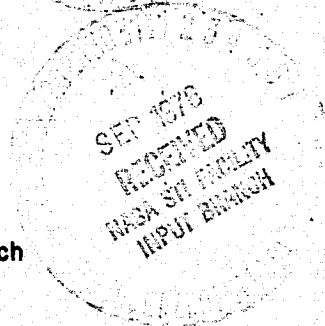
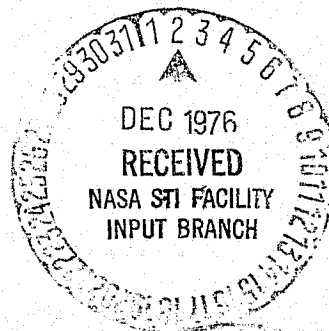
N77-11503

Unclas
G3/43 15419

for
NASA SR/T PROJECT NO. W-13,557
RED RIVER CHLORIDE REMOTE SENSING STUDY

As of 31 December 1975

Geology Section, Foundation and Materials Branch
U.S. Army Engineer District, Tulsa
P.O. Box 61 Tulsa, Okla. 74102



INDEX

ABSTRACT

TEXT

1. PROGRAM OBJECTIVES AND HISTORY
2. REMOTE SENSING ACQUISITION BY THE MOHAWK GROUP
3. HOW THE VARIOUS REMOTE SENSING PRODUCTS APPLY TO THE DISTRICT MISSION
4. DISCUSSION OF EXAMPLES
 - I. SLAR - SIDE LOOKING RADAR MOSAIC AND OVERLAYS
 - II. INFRARED THERMAL IMAGERY FLIGHT LINE MAPS
 - III. EXAMPLES OF INFRARED THERMAL IMAGERY
 - IV. INFRARED THERMAL IMAGERY AND COLOR PHOTOS
 - V. AERIAL PHOTO MOSAIC AND OVERLAYS
5. CONCLUSIONS

ABSTRACT

A Remote Sensing Program was flown for Tulsa District by the Mohawk Group from Fort Huachuca, Arizona, in July of 1973 as part of a NASA funded program to test and evaluate the application of Remote Sensing Data to the District Mission. The product acquired consists of side looking radar, infrared thermal imagery and color photography with a few examples of black and white panoramic photos taken from forward and vertical mounted cameras. Mission No. 1 was conducted primarily by the Tulsa District with assistance from Dr. Jack Rinker, ETL, and Mr. Ron Gelnett, SF District, concerning infrared thermal imagery and side looking radar, respectively. The overall program goals were to develop information from both the photography and imagery to determine if these products could be used to supplement the investigation of a natural saline pollution problem that is hydrologically and geologically oriented. The study area was explored concurrently by ground methods and a reasonably good understanding of the hydro-geologic conditions have been achieved. Development of detailed area geology in a region of this type requires surface field investigation, supplemented by subsurface borings. Likewise, hydrologic data of a qualitative nature to determine the salinity of surface waters requires field sampling and measurements. In so doing, familiarity is gained as to structural geology and the brine emission locations that are visually identifiable. Due to the vastness and inaccessability of much of this region, an overview of these objects to enhance the data that can be gathered by ground means is helpful. The remote sensing products provide a broader perspective of not only the known and obvious, but also provide a means by which the more subtle and unknown features can be defined and observed at less expense and greater ease. Examples of the products acquired, their interpretation, and use techniques are submitted in the text of this report.

RED RIVER CHLORIDE CONTROL REMOTE SENSING STUDY

FINAL REPORT

31 December 1975

TEXT

1. PROGRAM OBJECTIVES AND HISTORY. The remote sensing program was conducted to enhance the hydro-geologic investigation of a natural saline pollution problem that exists on the Red River (Texas and Oklahoma) and its principle tributaries. The program was observed by Remote Sensing Coordinators from the Corps of Engineers Chief's Office, Southwestern Division and Tulsa District. Mission No. 1 was conducted by District personnel with consultation from Dr. J. N. Rinker of the Photo Interpretation Research Division, ETL, who supplied expertise on the infrared thermal imagery and Mr. Ron Gelnett of San Francisco District who directed the SLAR acquisition. The mission was flown by the Army Mohawk Group out of Fort Huachuca, Arizona, under the direction of Major Urick and Captain Wolfe. The program was in part NASA funded and certain requirements were outlined for fulfillment of the contract. NASA's interest was in testing and evaluation of remote sensing application to the District's mission according to the capabilities of the Mohawk OV-1. Techniques used and provisions made to acquire, handle, interpret and present the product are discussed. The quarterly report, provided background on preflight planning, ground truth, imagery acquisition, and interpretation progress.

2. REMOTE SENSING ACQUISITION BY THE MOHAWK GROUP. Mission No. 1 was flown between 17-26 July 1973. The first several days entailed overflights of the area, testing of equipment, SLAR flights and preparation for the night time infrared mission flown on the 25-26 of July. Side looking radar, infrared thermal imagery, color photography and panoramic photography viewed from both nose and belly cameras were provided. Some color infrared film was exposed, but due to a camera malfunction this product was unuseable. The SLAR was flown at an altitude of 10,500 feet which provides a scale of 1:250,000. Each strip represents a width of 25 kilometers and some of the flight line paths are 100 miles in length. Based on ground truth, the infrared thermal mission was flown at the optimum time of day to provide maximum temperature contrast between the items of interest. The imagery was flown mostly at 1,000 and 4,000 feet above the terrain, with a few strips at 500 feet. The strip color photos were obtained over the same river and tributary reaches as the imagery. These are a 5" x 5" rolled format having stereo overlap along the flight line. The scale is approximately 1:12,000 or 1 inch equals 1,000 feet.

3. HOW THE VARIOUS REMOTE SENSING PRODUCTS APPLY TO THE DISTRICT MISSION. Part of the District's mission is to investigate, design and construct measures

to control the natural saline problem. The Arkansas (and Brazos River in Fort Worth District) are similarly polluted, but the current study on the Red River is limited to about 7,000 square miles in the vicinity of Childress, Texas, as shown on Fig. 1. Artesian springs and seeps carrying chlorides and sulphates, leached from the evaporite type bedrocks, pollute the major drainage systems of the area. Generally the bedrock consists of flat-lying cyclothems of Permian dolomite, gypsum and shale, overlain and underlain by formations composed principally of sandstone. Karst topography is developed in these materials. Approximately 1,000 feet of vertical section is directly involved. The overburden mantle is relatively thin, with bedrock commonly exposed at or near surface. This provides a condition from which such phenomena as joint and fracture control of both the internal and surface drainage may be observed. The side looking radar has some use in this type of investigation, although it is understood that there are other geological areas, having greater relief and more pronounced linears that are better adapted to this product. Standard U.S.D.A. black and white aerial photography, in combination with field checks, supports the SLAR interpretation. Bedrock porosity and salinity conditions are reflected by the type of vegetation they support. These differences can be seen by several types of remote sensing. Temperature contrasts exist between the brine emission and its surroundings. The saline waters flow subsurface, usually under artesian conditions, and are emitted in topographic lows as cool or cold waters. These waters contrast with the temperature of the adjacent surfaces, such as soil mantle, mineral encrustation and vegetation which are heated and reflect daytime or seasonal ambient temperatures. The temperature contrasts, ranging from as little as 1/2 degree centigrade up to 6 degrees, lend themselves well to the use of infrared thermal flown at night to detect the difference. Further discussion of ground truth data with references is given in subsequent paragraphs. The color photos, obtained along the same reaches of the river as the infrared thermal imagery, are very useful in the detection of salt flats and mineral encrustation adjacent to and for some distance downstream from the points of emission. The various remote sensing products used in combination with each other serve as a useful tool in definition of the salt pollution problem. Examples of the various products accompany this report as indicated in the index. The remainder of the report will be centered around a discussion of these examples which portray the usefulness of the interpreted product, as it applies to the District's mission. Some of the techniques used and methods of data presentation are discussed.

4. DISCUSSION OF EXAMPLES.

I. SLAR - Side Looking Radar. Example No. 1 represents an initial interpretation of the SLAR, presented on a mosaic reduction with six overlays. Before reduction, the original product had a scale of 1:250,000 or 1 inch equals 4 miles and was flown at an altitude of 10,500 feet above sea level.

SLAR is used to high-light linears and its more attractive features are that cloud cover does not interfere with its intended purpose and that it will penetrate a limited amount of vegetation. This provides an opportunity to view the surface without some of the normal interferences. In the region under investigation, vegetation is sparse and is readily penetrated by the radar. There was a varied amount of cloud cover involving thunderheads. Turbulence caused by these summer thermals resulted in instability of the aircraft which is reflected in the quality of the product. Many of the flight lines had to be reflight to try to overcome the turbulence. A midwinter flight might have eliminated this problem. The usefulness of SLAR is dependent on bedrock being near the surface, or there being a minimal amount of overburden cover. This condition exists over a large amount of the region under study by the Red River Chloride Control Project, but there are some areas where the overburden obscures the linears being sought. This is the case where sandstone is involved or soil has developed to such depths that it is farmed or otherwise obscures the more subtle features. The product is best adapted to regions of great relief and where the linear features are quite pronounced. Neither is the case in this region. Relief is on the order of 200 feet maximum and the linears are quite subtle. At this point a definition of linears would be in order. In certain regions these can be directly referred to as traces of fractures or cracks in the earth's surface, such as faults or joints. Probably, the classic example and one where SLAR has been used to the greatest advantage, is along the coast of California, whereas the San Andreas and associated faults occur as large scale features. No faults of this magnitude are present in the Red River area but the structural geology has been mapped and a number of faults are known to exist. Several have been identified in the field, some with as much as 150 feet of displacement and trace length of up to one-half mile or more. One such fault is shown on the overlay No. 4 with the upthrown and downthrown side indicated. Under close observation on the original mosaic, the offset or orientation of a small drainage system crossed by this fault is quite pronounced. Many such offsets have been observed in the highly-dissected terrain of this region. Not all of them can be related to faults, but a more subtle jointing phenomena has, under certain conditions, similar control and effect on the drainage. Trends have been developed in the SLAR interpretation such that a major, a minor, and a tertiary set of joints can be identified. Due to the low relief, the subtleness of the joints, the scale of the product and only partial exposure of bedrock at the surface, the interpretation requires enhancement from emphasizing phenomena. Since the bedrock is an evaporite section exhibiting karst features, the joint systems are reflected in the control, orientation and offsetting of the surficial drainage. Although, deep-seated faulting occurs occasionally, the jointing is essentially a surface feature. Some of the joints are probably associated with structural folding as shown by the presence of local anticlines and synclines. The removal and dissolution of halite, gypsum and dolomite under uniform conditions provides the condition for surficial fracturing or

jointing of the bedrock. Internal drainage or migration of meteoric waters through the soluble bedrock causes the karst topography to develop. The initial control of the drainage takes place internally or subsurface and as base levelling continues, this control is subsequently expressed in the surface drainage. It is best displayed in the youthful streams and tributaries, but with maturity, the joint control of the major streams is de-emphasized by gravity and the drainage relates more to the larger structural and topographic features. By close observation and interpretation of the optimum areas for joint detection and by projecting these findings from area to area, a regional joint set is developed as shown on overlay No. 4. Because the interpretation of these features is minute, as dictated by the scale of the product, overlay No. 5 was prepared to emphasize the linears detected. This is a method used only for presentation purposes, from which a nominal joint pattern was developed. It has no respect for the actual magnitude of individual joints, fractures or linears. Many other linears or lineal features were observed on the SLAR. Some are obviously resistant scarps; some may have to do with Pleistocene or ancient channeling, terracing or a combination. Many of these are unexplained but are present and oriented as they are, due to the character of the bedrock and forces acting upon it. There appears to be regional joint blocks, whereas the lineal orientation varies from the nominal. In many instances, this can be related to smaller structural features such as prominent, relatively tight folds. Regional dip is about 25 feet per mile to the southwest, but the flanks of several anticlines have dips of as much as 250 to 300 feet per mile (or $2\frac{1}{2}$ to 3 degrees as compared to a $\frac{1}{2}$ degree). Also, some of the anomalous linears are related to anticlines which are known producing petroleum traps or oil fields. A few of these anomalous linears have been plotted on overlay No. 6, but no attempt was made to define all of them or to distinguish between them beyond the scope of the Chloride Control study. Since detection of the linears are enhanced and made possible by the present day drainage systems, overlay No. 2 is presented as a supplement to the SLAR interpretation. The drainage overlay is also related to the locations of the Chloride Control Projects shown on overlay No. 3. The purpose for presenting culture on overlay No. 1 is to flag the presence of major highway systems, railroads, communities and other man-made features that could be misinterpreted as natural occurring linears. No attempt was made in this study to delineate between farm lands but it might be noted that fence lines show up very prominently in the SLAR. In summary then, the SLAR has been useful in helping detect and determine joint control drainage in a karst region, which provides the type of information needed for the District mission. This information reflects or indirectly points to the surface and subterranean migration of fluids as well as the occurrence or dissolution of halite, both of which are beyond the scope of this report.

II. INFRARED THERMAL FLIGHT LINES. Flight line maps have been prepared for all of the remote sensing products. Examples of those for the infrared

thermal imagery have been selected and put in a reproducible form for presentation in this report. The rest can be prepared and made available as a supplement to this report if there is an interest. Those submitted include Area IX on the North and Middle Pease River, Area V, XIII and XIV on the Prairie Dog Town Fork of the Red River, Jonah Creek and Salt Creek, respectively, and Area VIII and X on the South and Middle Wichita Rivers. Color photography was flown only on the Middle Pease River, PDTERR, Jonah Creek and Salt Creek. Special effort was given to the portion of the Middle Pease River where the abundance of salt load is contributed to this stream. More specifically, this North bank tributary is located about one and one-half miles downstream of Highway 83 bridge and is referred to as the Salt Sump. It was selected as a Mission Center and was the area where most of the ground truth measurements were made. Flights were taken parallel to the main stem of the river and also transversely or parallel to the salt contributing tributaries. A few geographical landmarks such as highways, communities and main tributaries are shown for orientation. For information, some photographs taken and captioned by Dr. Rinker have been included in this report. Figures 2 and 3 are of Area IX, the Salt Sump or Mission Center. The temperature measurements on Table 1, submitted as Figure 4, were from this area. Additional ground truth data was also obtained on the Middle Pease River at the Salt Tributary and at Spring 1 in Area VII on North Wichita River and near Spring 4 in Area VIII on the South Wichita River. Figure 5 shows several of the other major salt contributing areas of the Red River Chloride Control Project.

III. EXAMPLES OF INFRARED THERMAL IMAGERY. Example III is a reproduction of the actual imagery flown at about 1,000 feet above the Mission Center. There is no reduction involved and the ground scale is approximately 1 inch equals 167 feet. A duplicate negative, a positive print and a duplicate positive is submitted. These should provide the reviewer with a negative and a positive for comparison, and also an overlay interpretation to observe the method by which the product is being applied to the Chloride Control Project. The best procedure for interpretation is by viewing the original imagery or a duplicate negative over a light table under magnification. On the negative, light tones represent cool temperatures and the dark tones represent warm temperatures. The opposite is true on the positive. As has been previously stated, the formation waters, or waters that originate beneath the surface, maintain a relatively constant low temperature in comparison to their surroundings, as they are emitted at the surface. These temperature contrasts are shown on Table 1. On the overlay of the duplicate positive, the interpretation was done in color as explained in the legend. From examination of the tones, coupled with previous knowledge of the emission areas, the major emission is somewhat obvious and is depicted in red. Further study and interpretation of the tones points to suspected emissions which have been assigned an orange color. If the saline emission is directly into a body of ponded water, it

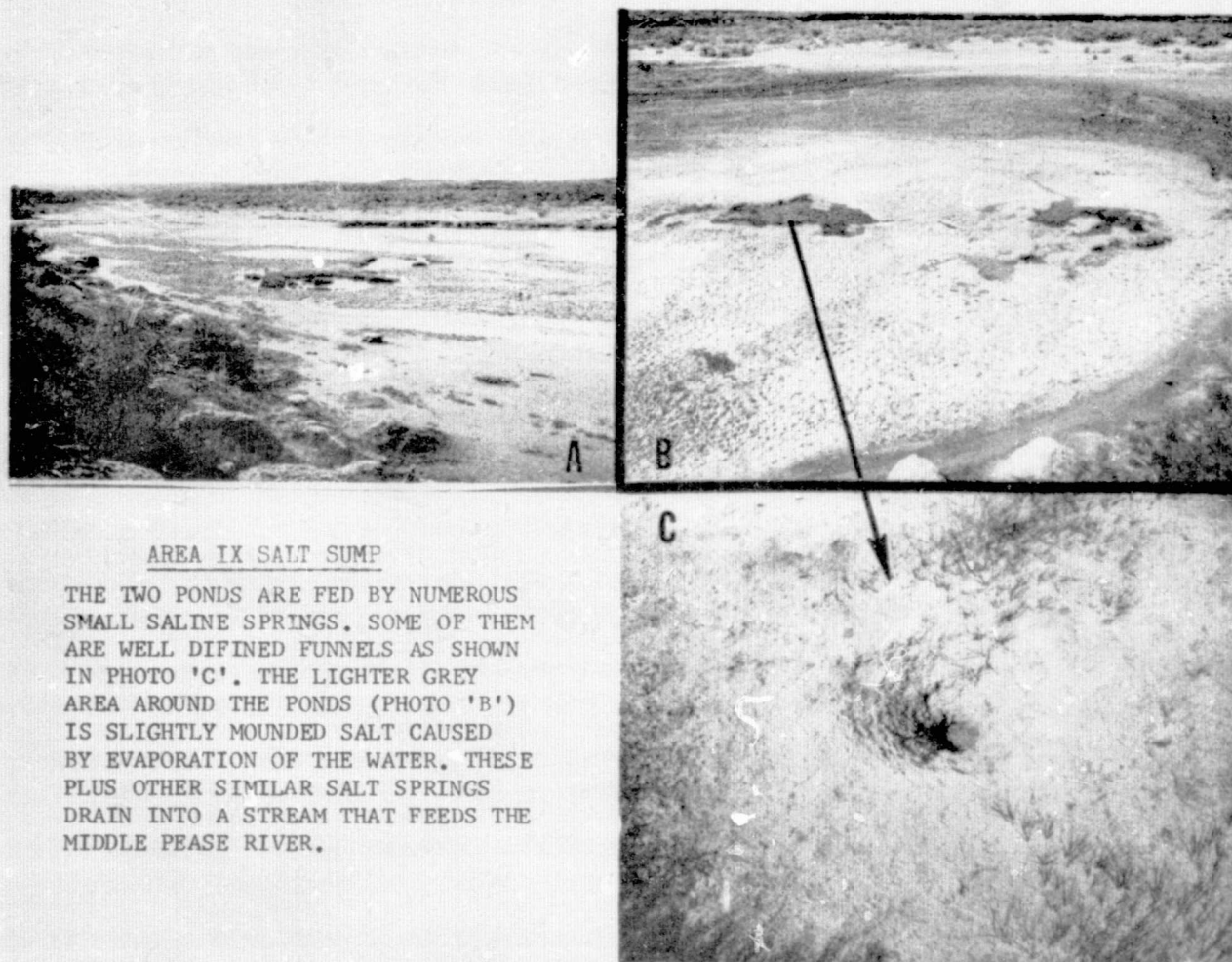
is immediately warmed and can be regarded as outflow from the emission areas. In some areas where there is insufficient warming, it flows to the main stem as cool water. This is shown in green but it is understood that along these reaches of outflow there is additional emission which is difficult to define other than with a first-hand knowledge of the condition. Further field checks may be required to verify these conditions. Several of the areas, where salt flats accompany the emission, lend themselves to a method of control involving well fields. This collection procedure is needed to lower the water table so that the salt encrustation is prevented, thereby diminishing the total load to be flushed out subsequently by rainfall or flooding. For this reason, in addition to identifying the emission, it is also necessary to identify the salt flats or mineral encrusted areas. Because of lesser temperature contrasts and the non-quantitative nature of the scanner, the infrared thermal imagery is not in itself the best method of defining the salt flats. When used in conjunction with color photography, which is excellent for this purpose, the imagery provides a base map on which to plot the data, and supports a comprehensive interpretation. The boundaries of the salt flats and saline affected areas are colored in yellow. Complete understanding of the formation of the salt flats has not been established but this procedure indicates suspected or probable emissions in the upper ends of these areas. It may be found that the salt flats occur due to the development of a saline water table caused by artesian or capillary action and its lateral spreading is due to a process of headward erosion or degradation. Again, this is beyond the scope of this report but bears on the control method selected for the Chloride Control Project. As a better understanding of the processes are gained, the interpretation procedures will be adjusted accordingly. As shown in Table 1, temperature contrasts are as much as 6 degrees centigrade between the springs and some of the surroundings. The readings represent a comparison between a radiometer and a contact pyrometer. Occasional measurements of the sky at zenith show it to be very cold. Aluminum test panels were set out at the Mission Center to reflect this temperature analogy. Charcoal fire pots were used and may be seen as a hot spot on the imagery. Vehicles are also apparent on the examples. Further evaluation of the imagery is given in Paragraph 5 entitled Conclusions.

IV. INFRARED THERMAL IMAGERY AND COLOR PHOTOS. As a use and presentation technique, examples of the remote sensing product were selected and mounted on 4 x 8 foot boards and photographs taken for inclusion in this report. Boards No. 1, 2 and 3 shown as Example IV include infrared thermal imagery and color photography of Area IX, Areas V, XIII, XIV and the Prairie Dog Town Fork of the Red River. High altitude overviews flown at 4,000 feet above the terrain were selected, assembled and mounted as a mosaic representing these areas. Intermediate altitude imagery flown at 1,000 feet above the major salt contributing areas were interpreted in color as described under Example No. 3. These were mounted adjacent to the mosaic for study and comparison.

Coloring of the positive masks the object being observed and is lost in duplication. For this reason, several untouched images are also mounted on the board. As has been previously stated, use of the color photography in conjunction with the infrared thermal imagery provides data for a more complete interpretation. For this reason, color photos of the prominent salt flats are included. Due to the reduction for presentation in this report, these exhibits serve no immediate purpose other than submitting a use technique. This procedure has proven to be a very satisfactory method for handling and studying the products. With proper equipment, the rolled format allows only an individual the means to view and interpret the product. By selection and mounting only pertinent examples on 4 x 8 foot boards, a means is provided by which reviewers and interested parties may observe the interpreted product in context. Similar boards are being prepared for the other areas where the imagery was acquired such as Areas VIII and X on the South and Middle Wichita Rivers, respectively. These can be made available upon request as a supplement to this report. After the low and intermediate altitude imagery was interpreted, the data was transferred to the high altitude imagery mosaics primarily for completeness only. The high altitude imagery makes an excellent overview but does not provide sufficient detail due to the size of the targets. It is a trade off as to which altitude yields the best data, but in the initial mission, the Mohawk Group supplied an excellent variety of altitudes and scales for the purpose intended.

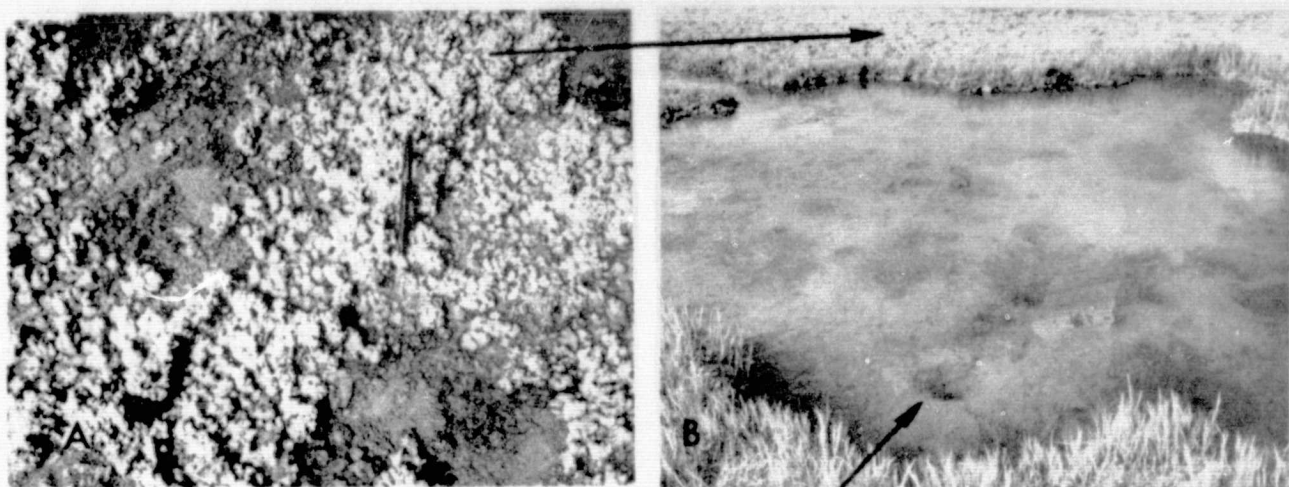
V. AERIAL PHOTO MOSAIC AND OVERLAYS. The U.S. Department of Agriculture 9 x 9 inch black and white photographs were available for use prior to acquiring the Mohawk product. A mosaic was mounted on a 4 x 8 foot board and overlays prepared for Area IX. The overlays for Board No. 4 represent (1) areal geology, (2) drainage (3) linear interpretation. Areal geology was developed by field studies and serves as the remote sensing base as well as the basic data from which the chloride control problem areas were delineated. Again, because the interpretation was done in color, that drop out during reproduction, the data is presented here only as an example of an interpretation technique. Overlay No. 2 which shows the drainage serves for orientation and complements the linear interpretation. Overlay No. 3 represents a linear interpretation for a remote sensing product other than the SLAR. This study was made after, and somewhat in support of, the SLAR interpretation. Field checks were made to confirm the presence of joint controlled drainage and a combination of the three approaches provides ideal coverage. As with the imagery, trade offs can be gained by viewing the object from various distances. Whereas, viewing the object from surface level in the field has some advantages, the overview is equally as important. The overview would have very limited value without the benefit of surface field geology. Here the 1 inch equals 1,676 feet scale photographs, provide an intermediate scale view and serves as a companion remote sensing product. Somewhat in keeping with the philosophy of PIRD, the black and white aerial photography has been for years the work horse for the remote sensing community.

5. CONCLUSIONS. The data obtained from Mission No. 1 is being used by the District to supplement its field investigations for the Red River Chloride Control Project. All of the products acquired have some benefit individually but are more beneficial when used in combination with each other and in conjunction with the ground acquired hydro-geological data. The Phase I report for the Red River Chloride Control Project is scheduled for submittal in January of 1976. With this as a priority, the remote sensing products were used to enhance this phase of the investigation. After a sufficient digest of the data, the Chloride Control Project will require additional study and many refinements of the initial investigation will result. Likewise, the remote sensing products will have a continuing usefulness. Because of the scope and nature of the problem each subsequent study beyond the initial interpretation will result in additional refinement and benefits. The SLAR has very little value by itself for definition of subtle linears in a region having low relief, without the emphasis added by the regional drainage pattern developed in the soluble bedrock. It was worthwhile to confirm the presence of joint controlled drainage, and it has indirectly served in defining the occurrence of subsurface halite. The infrared thermal imagery can be used advantageously to detect or confirm the major brine emission locations. Many of these locations were previously known but the imagery did aid in the detection of suspected or subtle emission areas along less familiar reaches of the drainage systems. Whether it is a self-supporting entity for the detection of saline seeps is yet to be determined. Its usefulness is dependent-on and enhances previous knowledge and understanding of the object being sought. Used in conjunction with other methods or remote sensing products, the imagery can prove to be very useful and beneficial to the District's mission. The same can be said for the strip color photography, in that it readily indicates the location of salt flats and mineral encrustations. Since this type of information is necessary for the design and support of the proposed controls, both the color photography and the infrared thermal imagery will have a continuing use and application. The Mohawk Mission is regarded as successful.

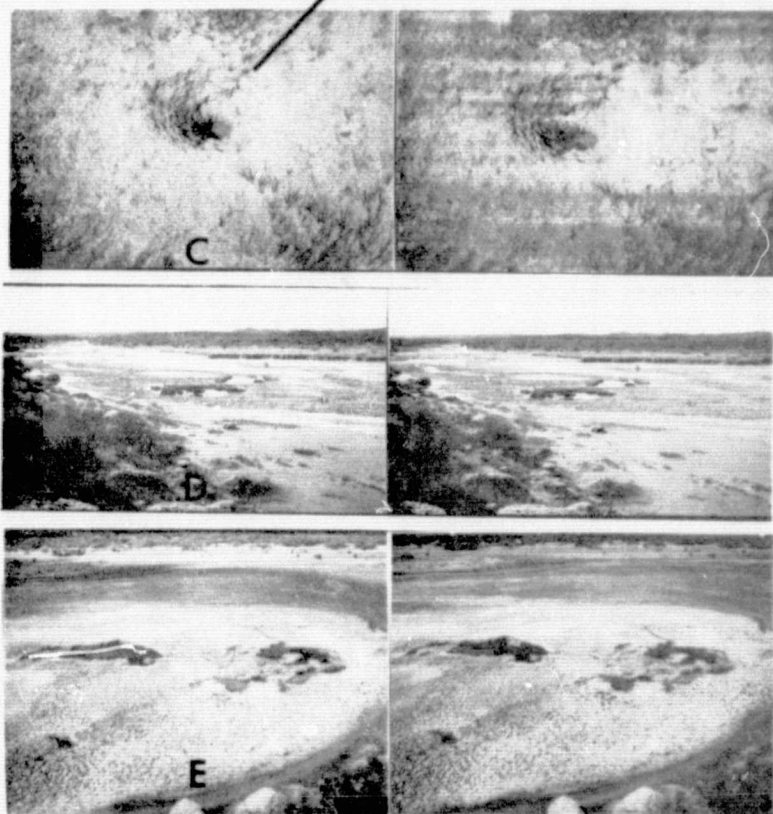


AREA IX SALT SUMP

THE TWO PONDS ARE FED BY NUMEROUS SMALL SALINE SPRINGS. SOME OF THEM ARE WELL DIFINED FUNNELS AS SHOWN IN PHOTO 'C'. THE LIGHTER GREY AREA AROUND THE PONDS (PHOTO 'B') IS SLIGHTLY MOUNDED SALT CAUSED BY EVAPORATION OF THE WATER. THESE PLUS OTHER SIMILAR SALT SPRINGS DRAIN INTO A STREAM THAT FEEDS THE MIDDLE PEASE RIVER.



Ground photos from the saline spring area at the salt sump of Area IX. Photos D and E are stereo pairs overlooking the river valley from a bluff along the north side. Two springs can be seen. The light area in stereo E is an accumulation of salt left from the evaporation of saline spring water, and this process has gradually built a mound several inches higher than the nearby valley floor. Photo B is a view of one of the salt springs shown in stereos D and E. Salt water flows into the basin through many openings in the bottom. Stereo pair C is a closer look at one of the funnel shaped openings in the foreground of the spring in photo B. This particular opening was about a foot across at the top and perhaps a foot deep. Photo A is a closeup of the salt deposit that forms the mound around the springs. This particular set of springs is not a problem in detection, since it is visible equally to the eye, the infrared thermal scanner, and photo emulsions. Note the change in tones between D and E. In D, looking more towards the sun, the shadow sides of the rough salt deposits are darker than the surrounds. In E, the reverse is true, since the view is away from the sun, and the rough salt surfaces are reflecting more light back to the camera station than the smooth valley floor. The temperature measurements of Table 1 were from this area. Stations A and B were in the vicinity of the springs, and the stations from B to X stretched across the valley to the higher land in the background.



ORIGINAL PAGE IS
OF POOR QUALITY

Fig. 3

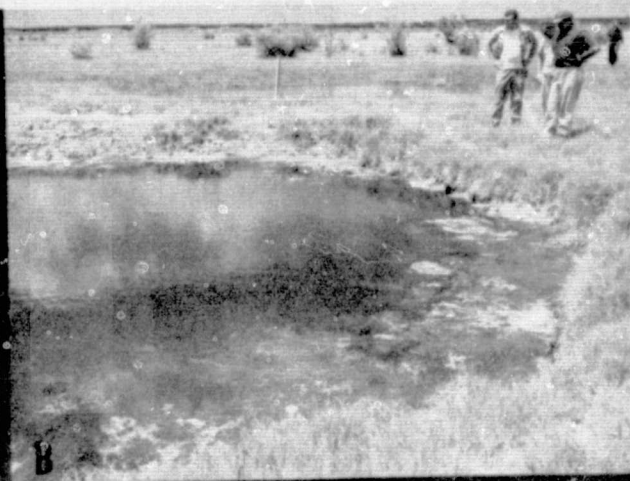
TABLE 1

TIME	TARGET	°C		
		T _R	T _C	S _Z
2148	K salt on silt	26	26 3/4	
2151	L water	23	23 3/4	
2152	M salt on silt	27	28	
2153	N water (1/2" flowing)	23	23	
2155	O salt grass on silt	25	27 1/4	
2156	P water	22	22 1/2	
2158	Q salt on silt	27	28 1/2	
2201	R salt on silt	28	28 1/2	2
2203	S grass on sand	25	25+	
2218	T grass on sand dune (missed & returned)	24	26 3/4	
2205	U Juniper tree	22		
	V sandy ground adjacent	24	25 1/2	
2209	W First high ground	24	29	
2211	X salt water bog	24	25	
2115	U Juniper tree	22		
	V ground adjacent	24		
2220	Q salt on silt	26 1/2		
2222	P water	21		
2224	O salt grass on silt	25	26 1/4	
2225	N water (1/2" flowing)	22		
2226	M salt on silt	26		
2227	L water	22 1/2		
2227	K salt on silt	26		2
2228	J sand	22		
2228	I salt grass	21 1/2		
2229	H salt on sand	24	25	
2229	G salt on silt	26 1/2		
2230	F salt grass	25		
2231	E salt on silt	26	26 1/2	
2231	D salt on silt (wet)	25		
2232	C salt on silt (wet)	22 1/2		
2233	B water	22	23	
	salt adjacent	22 1/4		
2234	A salt (dry)	26 1/2	27 1/4	
	salt (wet)	24 1/2	26 3/4	2

ORIGINAL PAGE IS
OF POOR QUALITY



A



B



C

SALINE WATER - TEXAS

- A - ESTELLINE SPRING - SALTY
- B - SINKHOLE NEAR ESTELLINE - FRESH
- C - AREA VIII - SPRING 4 - SALTY
- D - AREA IX - SALT CREEK - SALTY
- E - AREA VII - SPRING 1 - SALTY



D



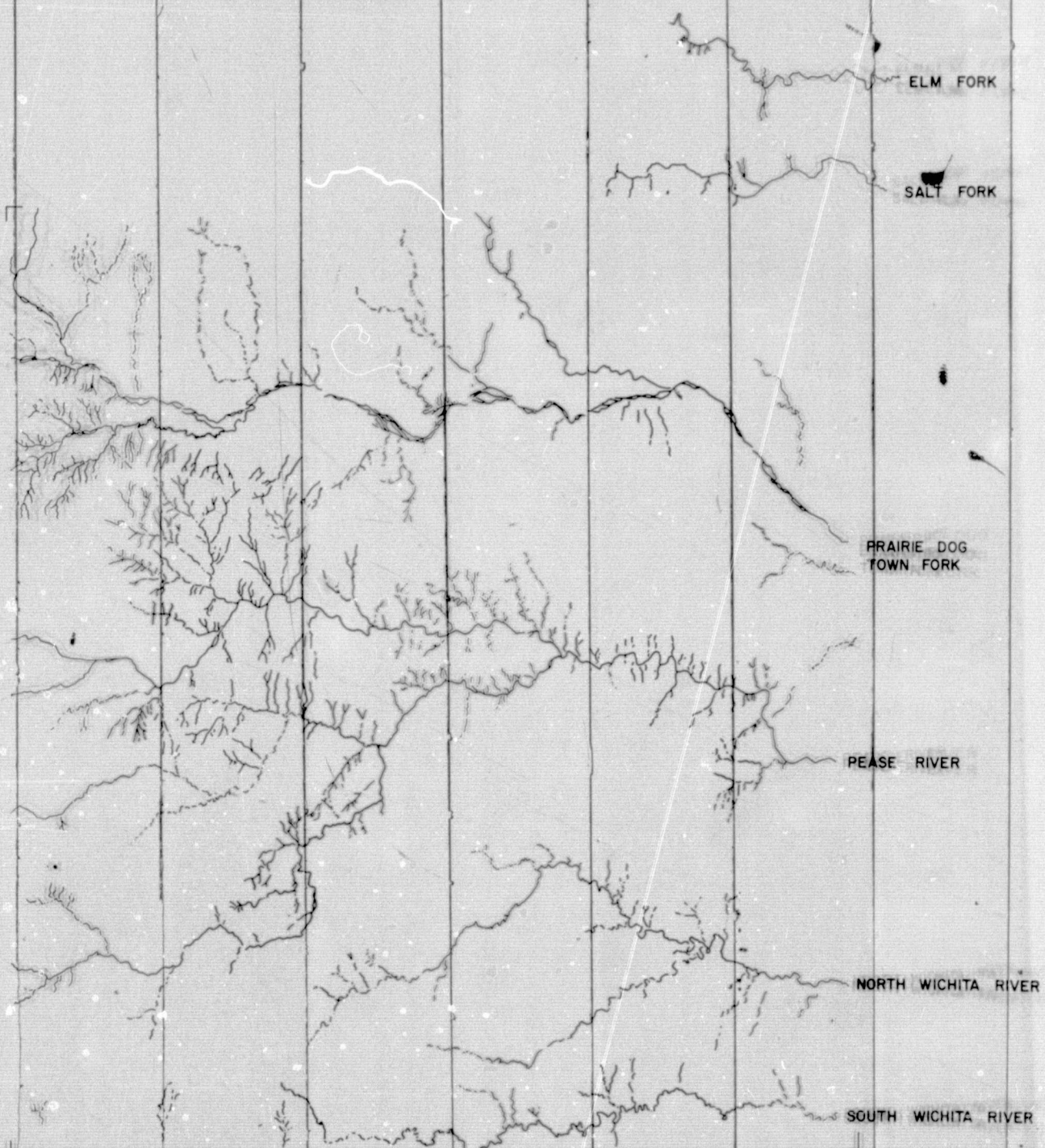
E

Fig. 5

I. CULTURE



2. DRAINAGE



3. CHLORIDE CONTROL PROJECTS

FISH CREEK B.D.



VI

XIII

XIV

II

IV

IX



CROWELL B.D.



VII

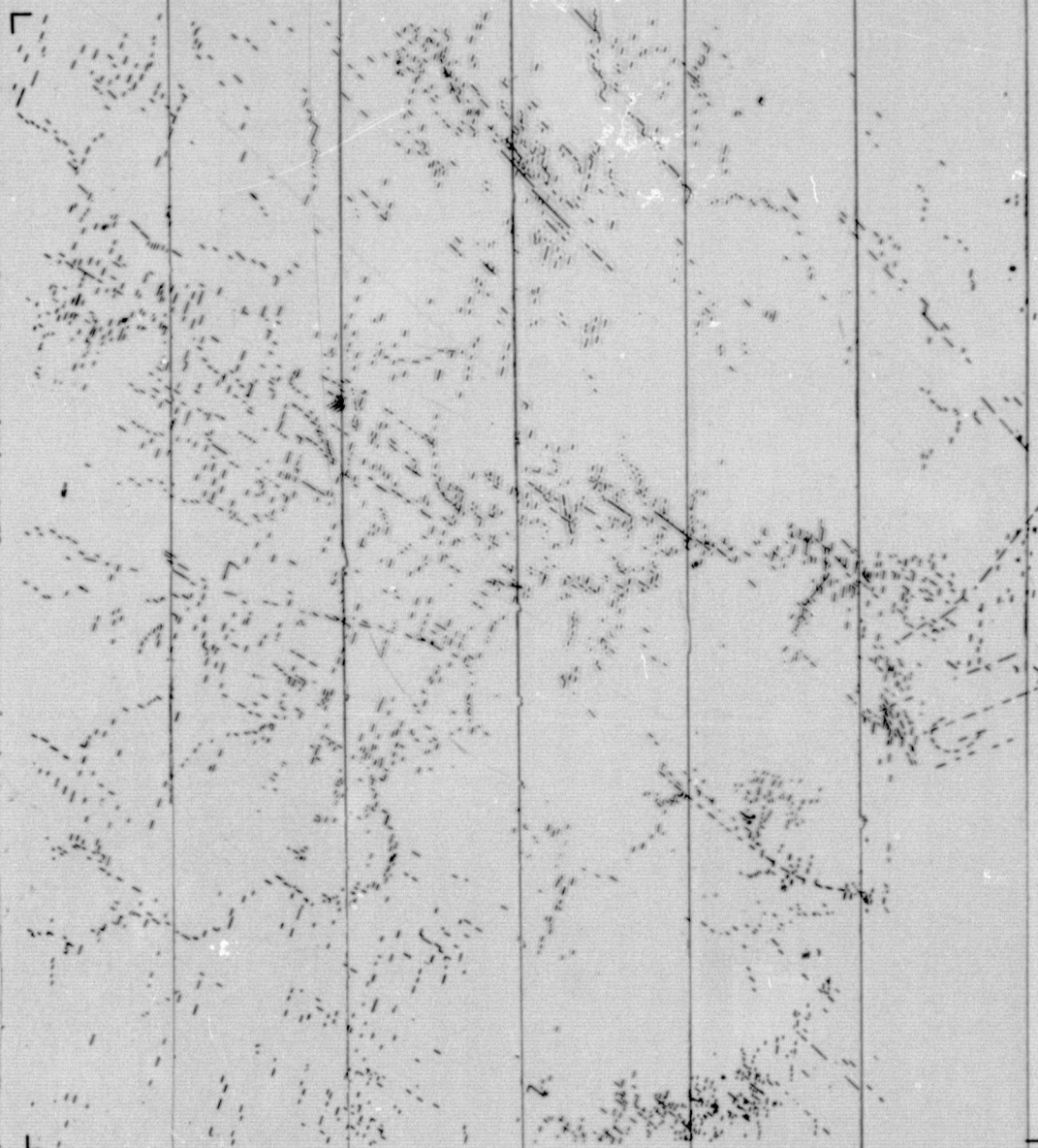
TRUSCOTT B.D.



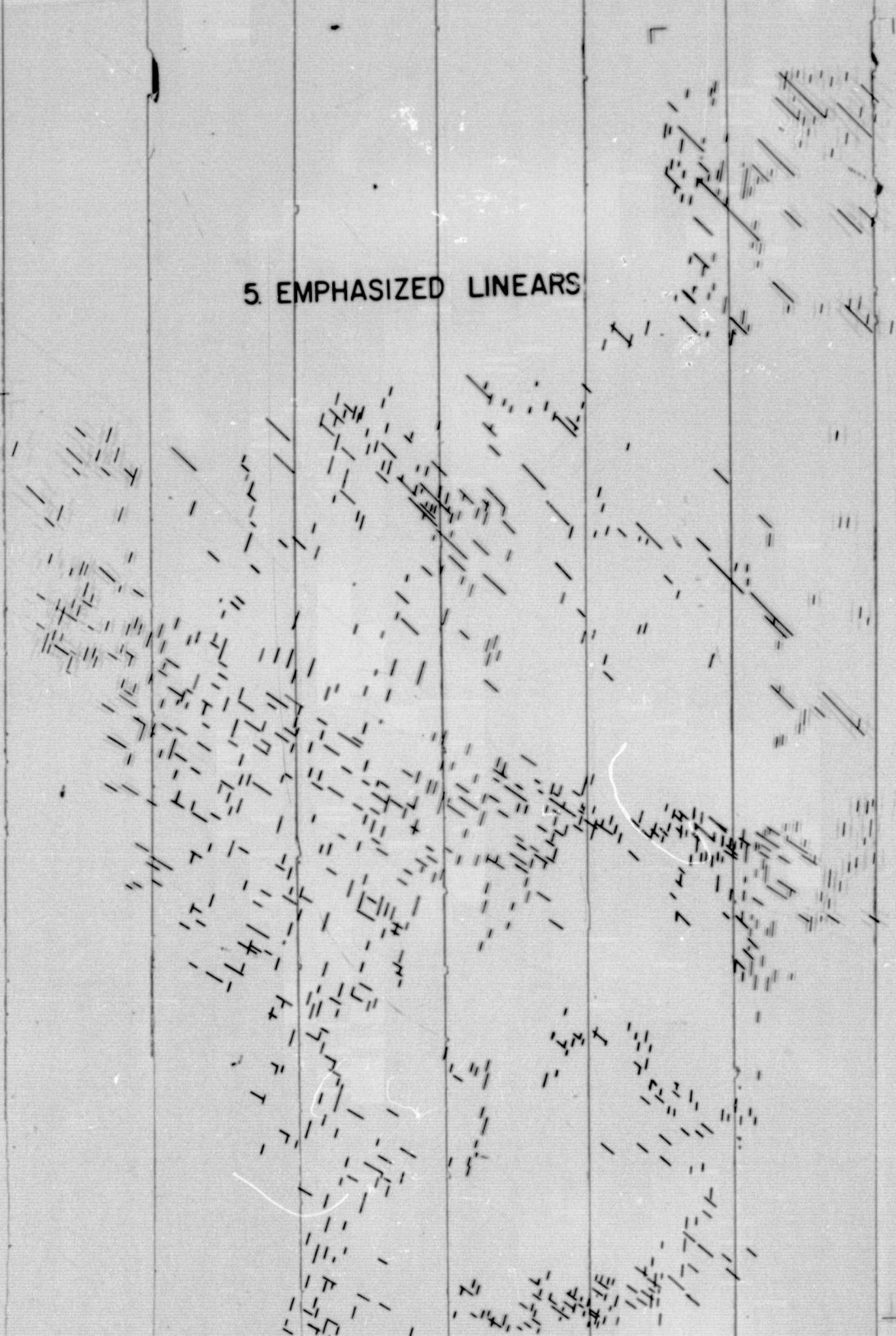
I

V

4. LINEARS

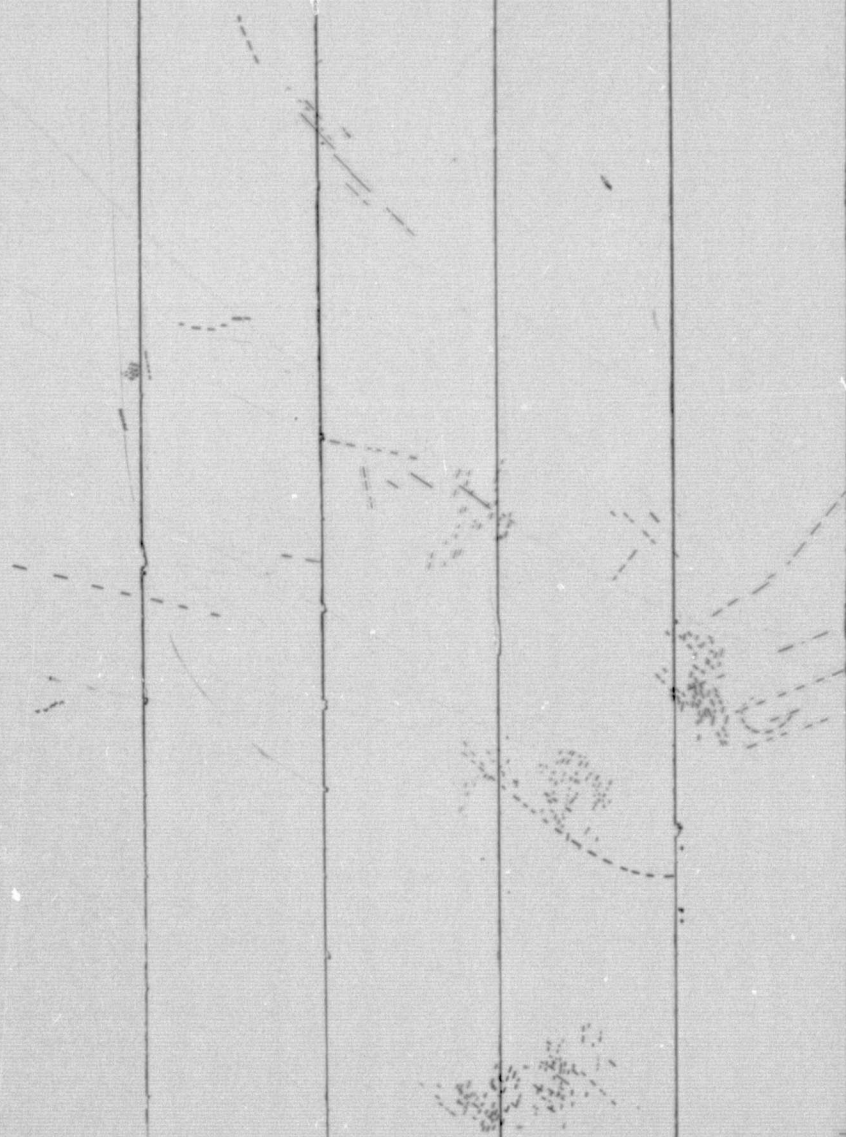


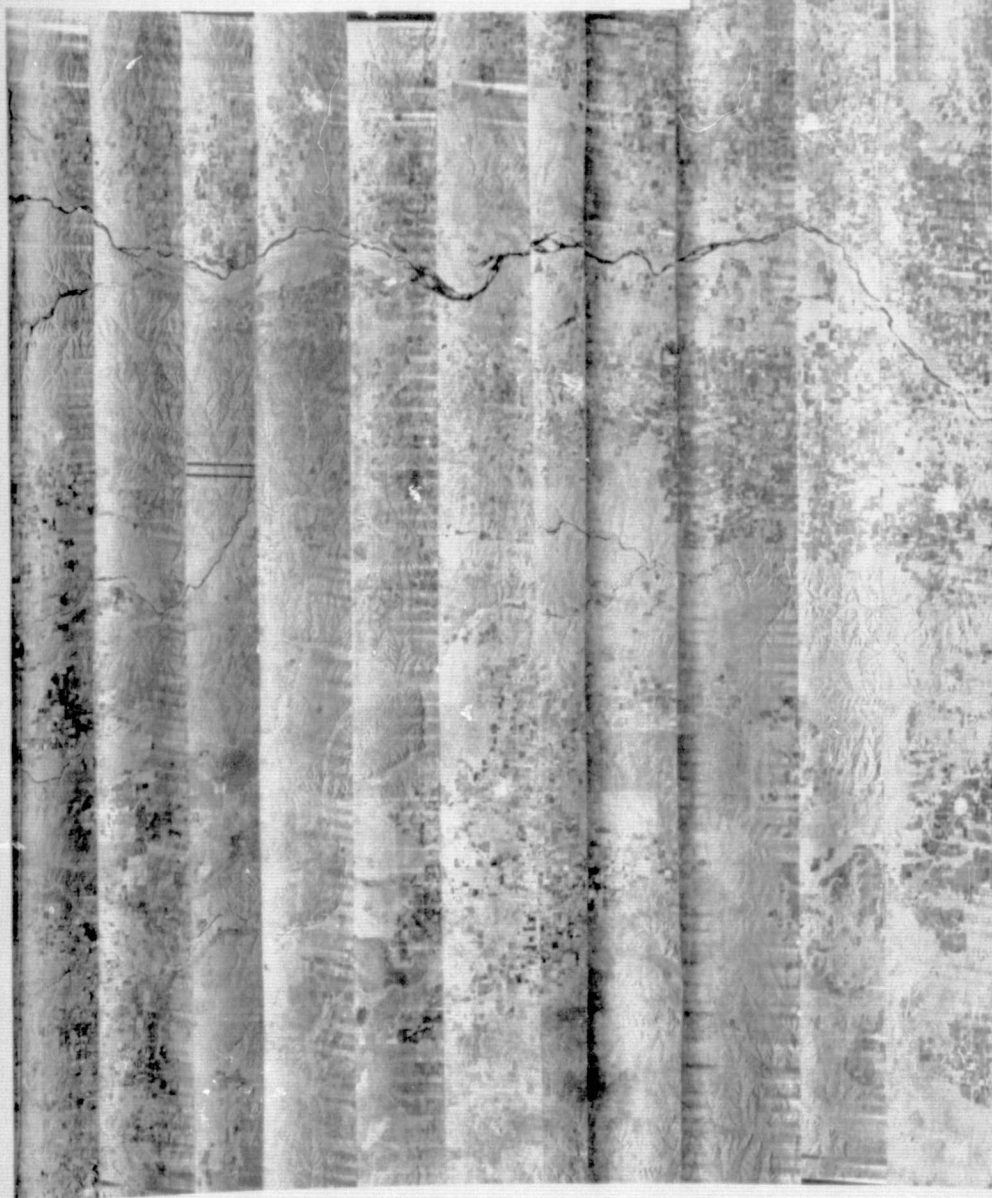
5. EMPHASIZED LINEARS



NOMINAL LINEAR ATTITUDE

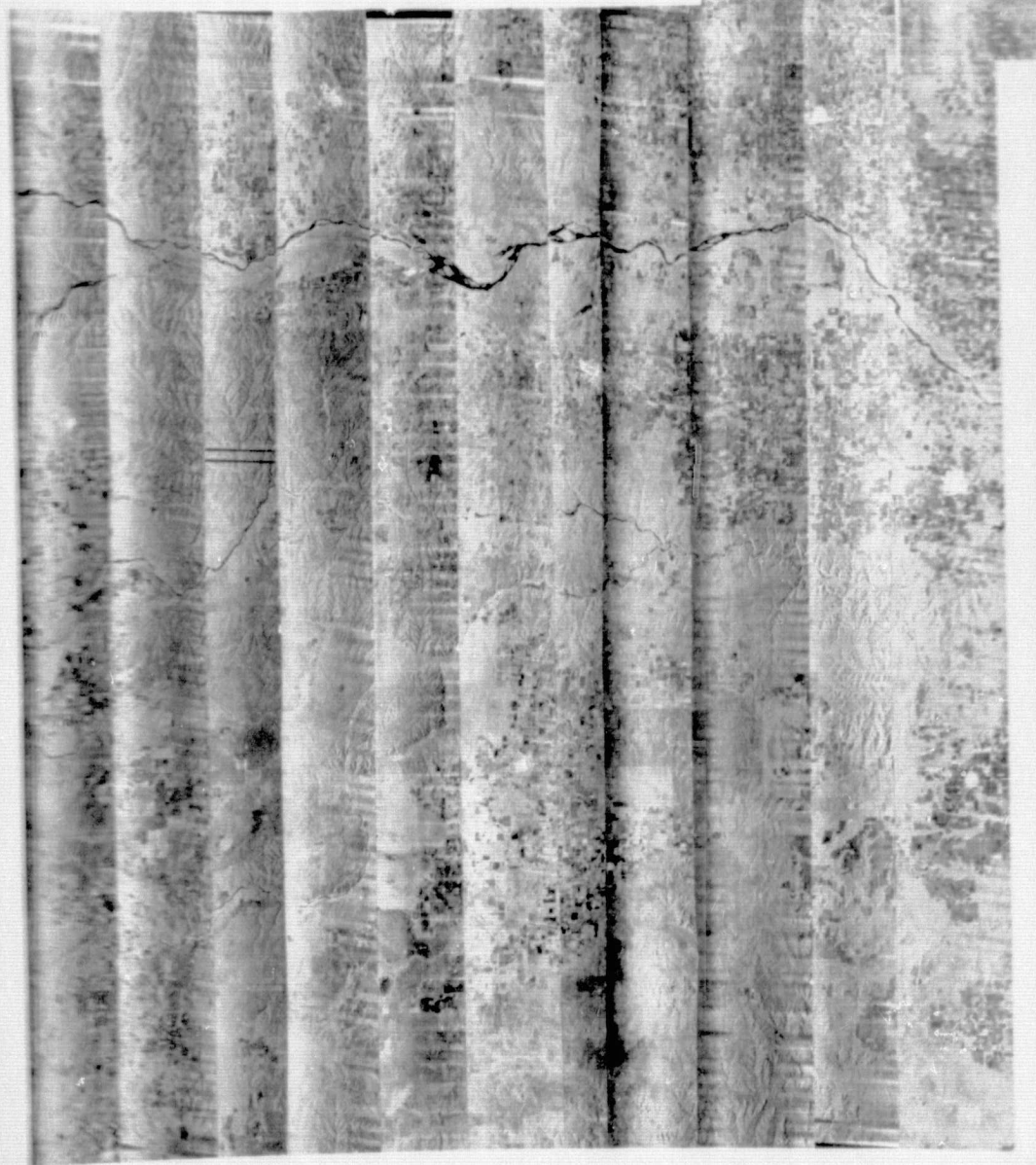
6. ANOMALOUS LINEARS





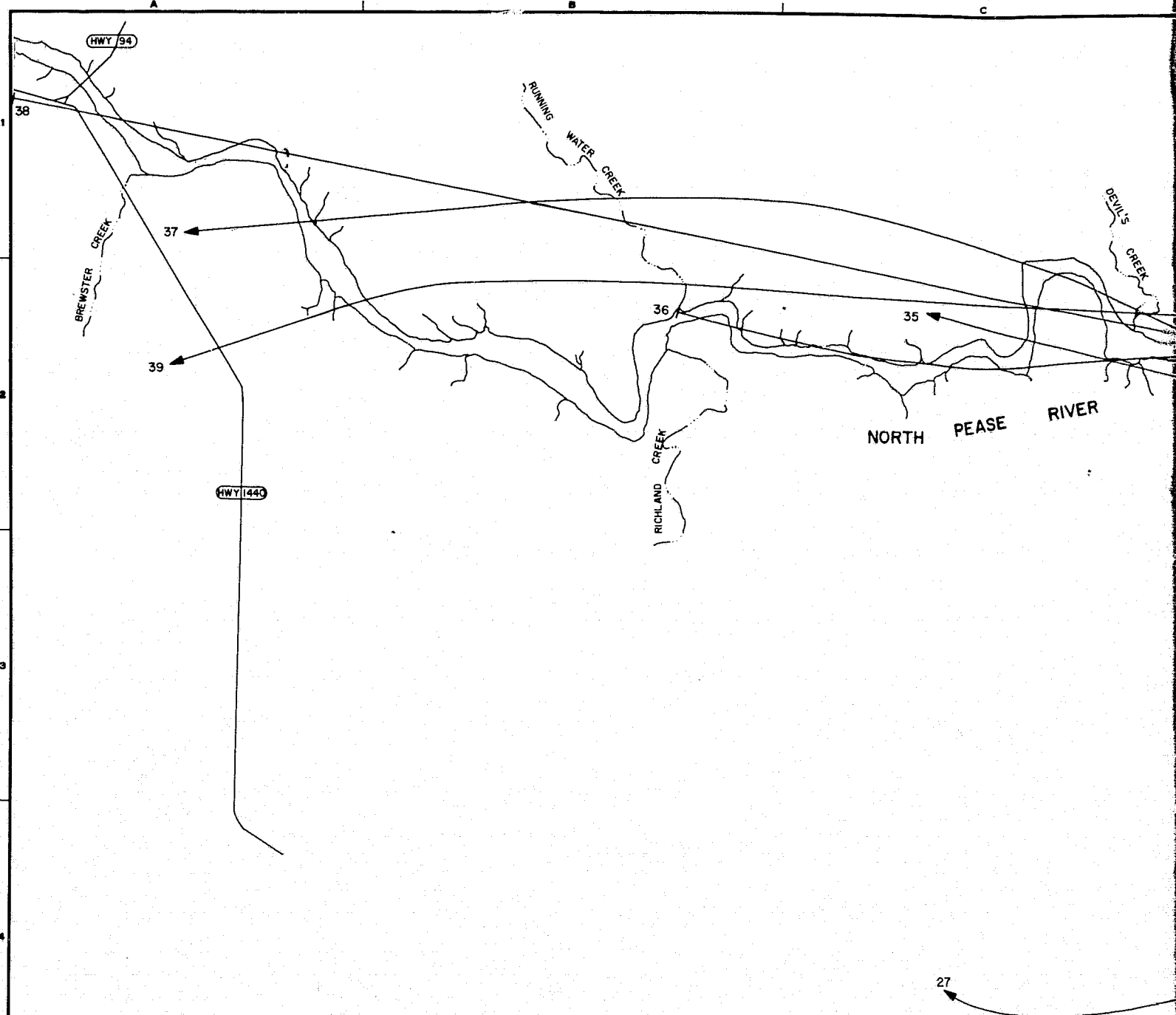
ORIGINAL PAGE IS
OF POOR QUALITY

SLAR
MISSION NO 1 JULY 1973
RED RIVER CHLORIDE
TULSA DISTRICT C OF E

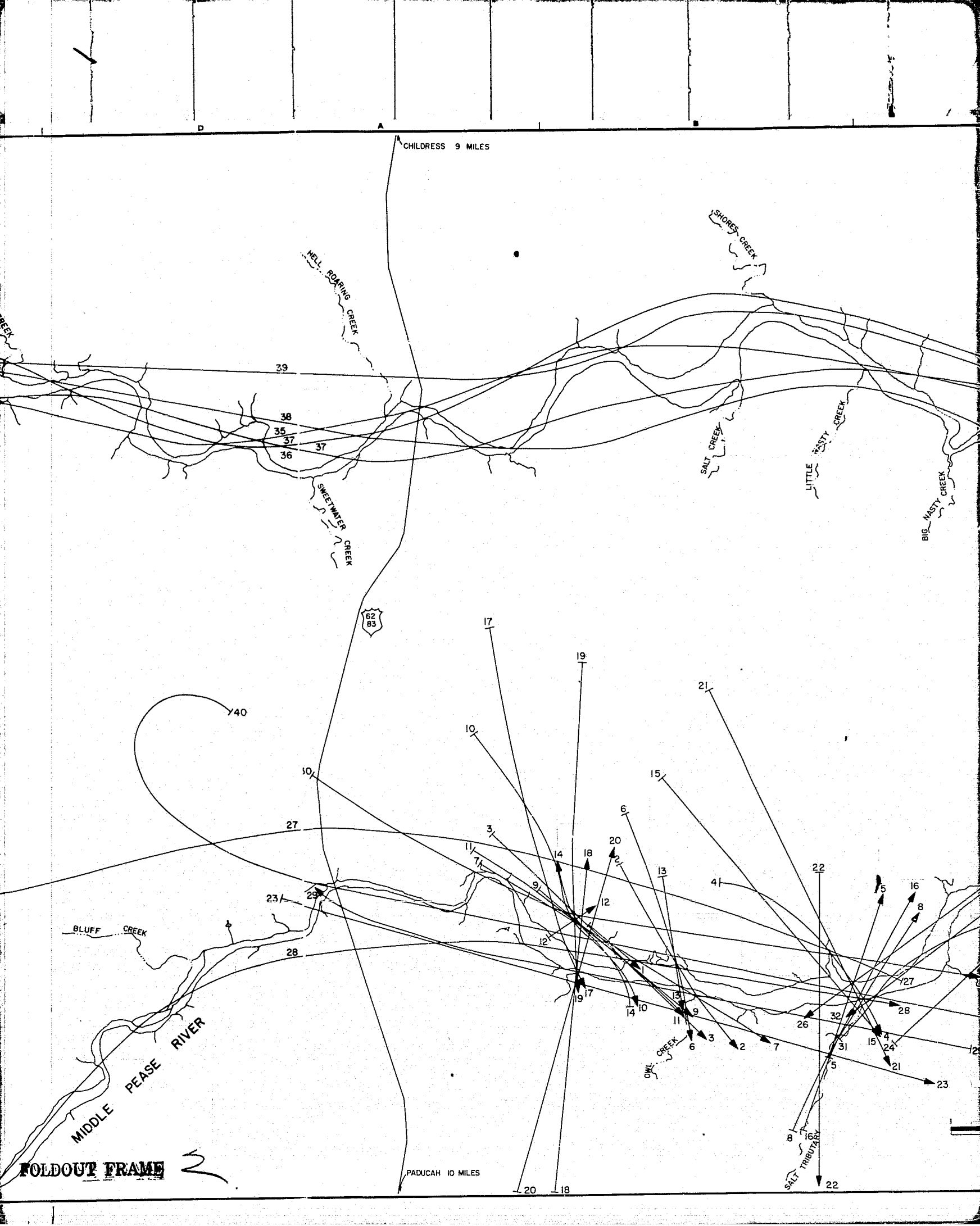


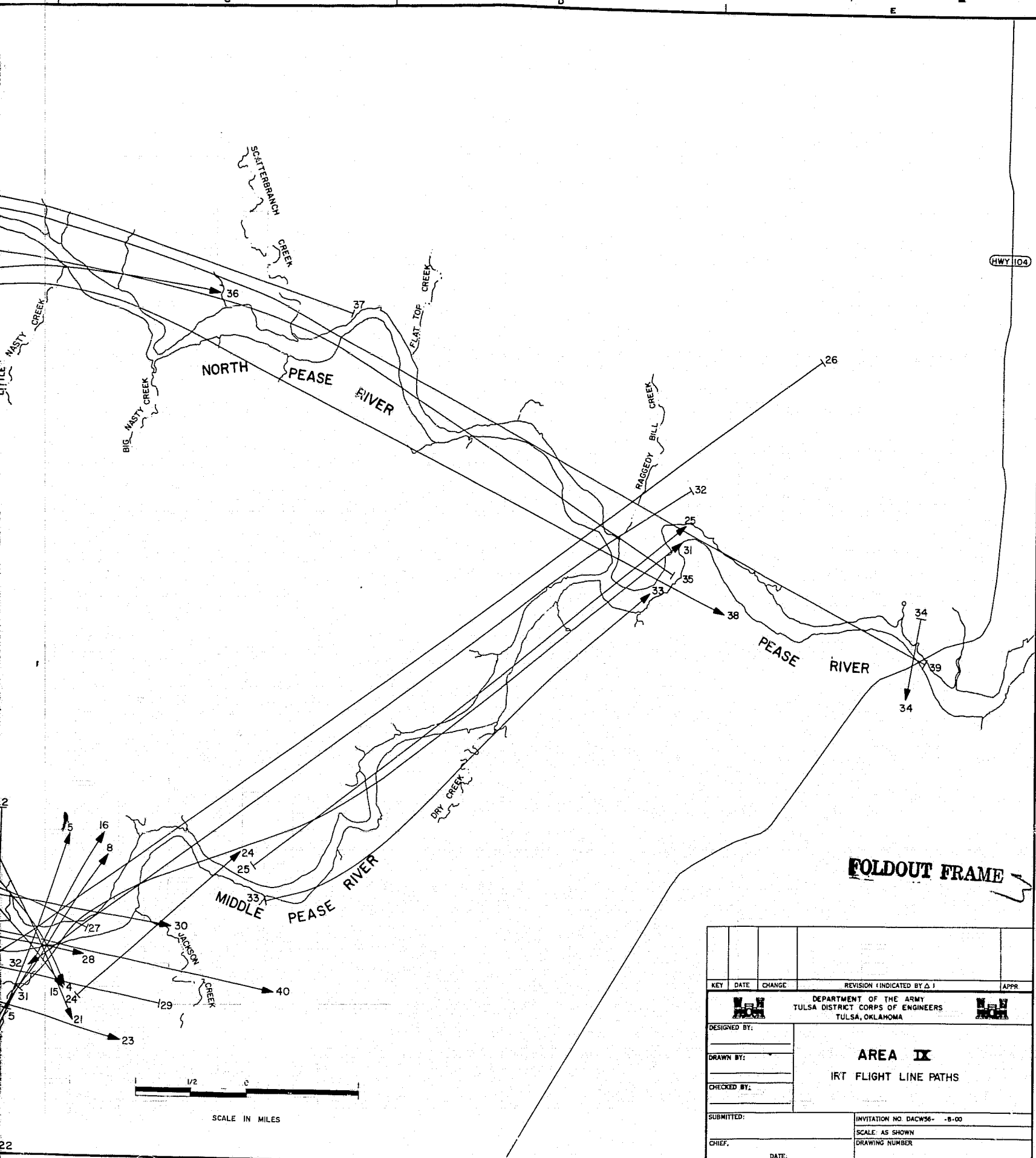
ORIGINAL PAGE IS
OF POOR QUALITY

SLAR
MISSION NO 1 JULY 1973
RED RIVER CHLORIDE
TULSA DISTRICT C OF E



FOLDOUT-FRAME /
ORIGINAL PAGE IS
OF POOR QUALITY





KEY	DATE	CHANGE	REVISION (INDICATED BY Δ)	APPR
<p>DEPARTMENT OF THE ARMY TULSA DISTRICT CORPS OF ENGINEERS TULSA, OKLAHOMA</p>				
DESIGNED BY:		<p>AREA II IRT FLIGHT LINE PATHS</p>		
DRAWN BY:				
CHECKED BY:				
SUBMITTED:				
CHIEF,		<p>INVITATION NO. DACW56- -8-00 SCALE: AS SHOWN DRAWING NUMBER</p>		
DATE:				

MEMPHIS

HWY 287

PARKER CREEK

INDIAN CREEK

PRAIRIE

FR 657

TURKEY 10 MILES

LITTLE RED RIVER

ESTELLINE

TOWN

DOG

JONAH CREEK

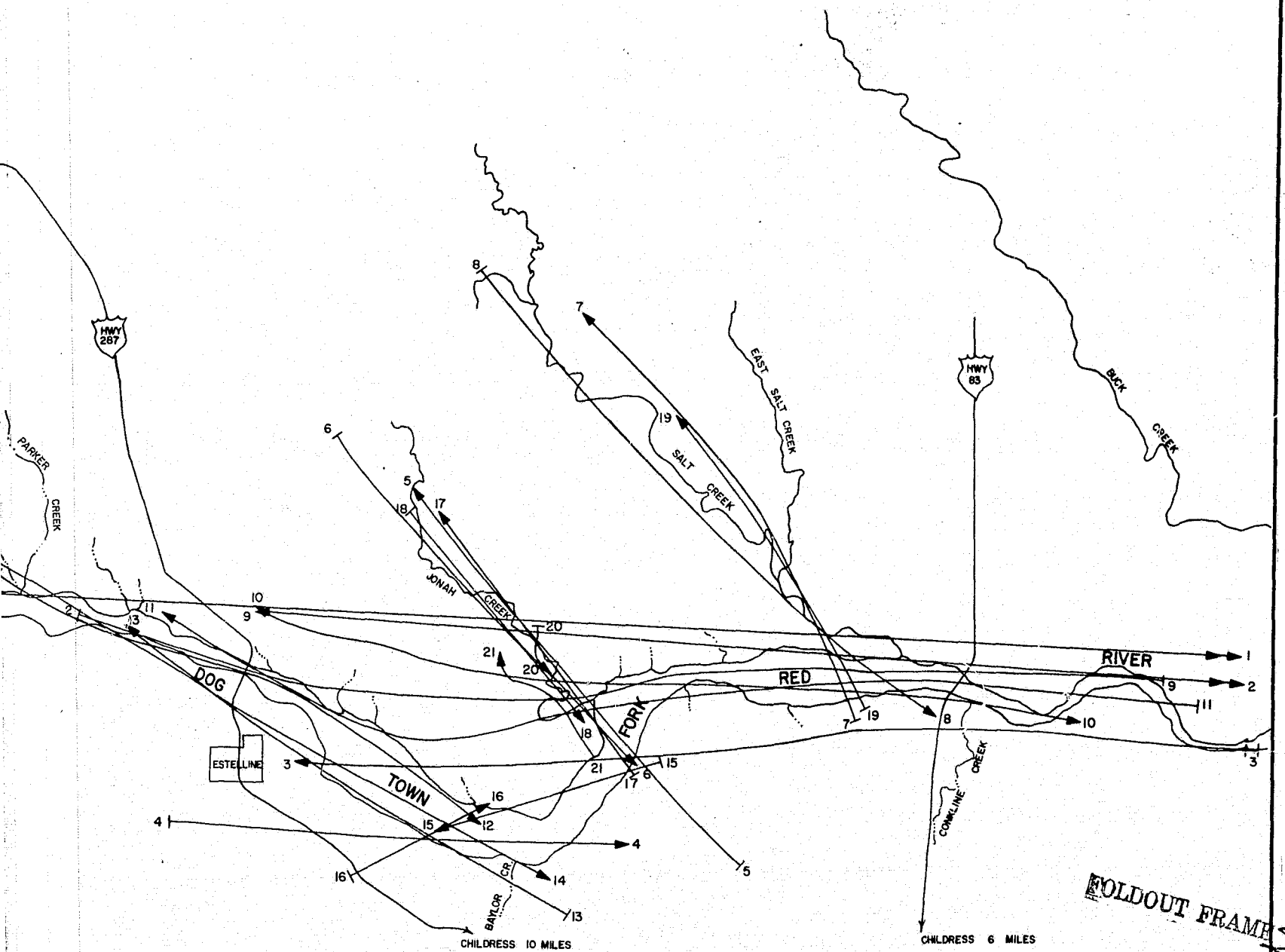
CHILDRESS



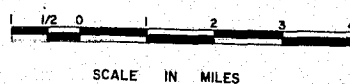
SCALE IN MILES

ORIGINAL PAGE IS
OF POOR QUALITY

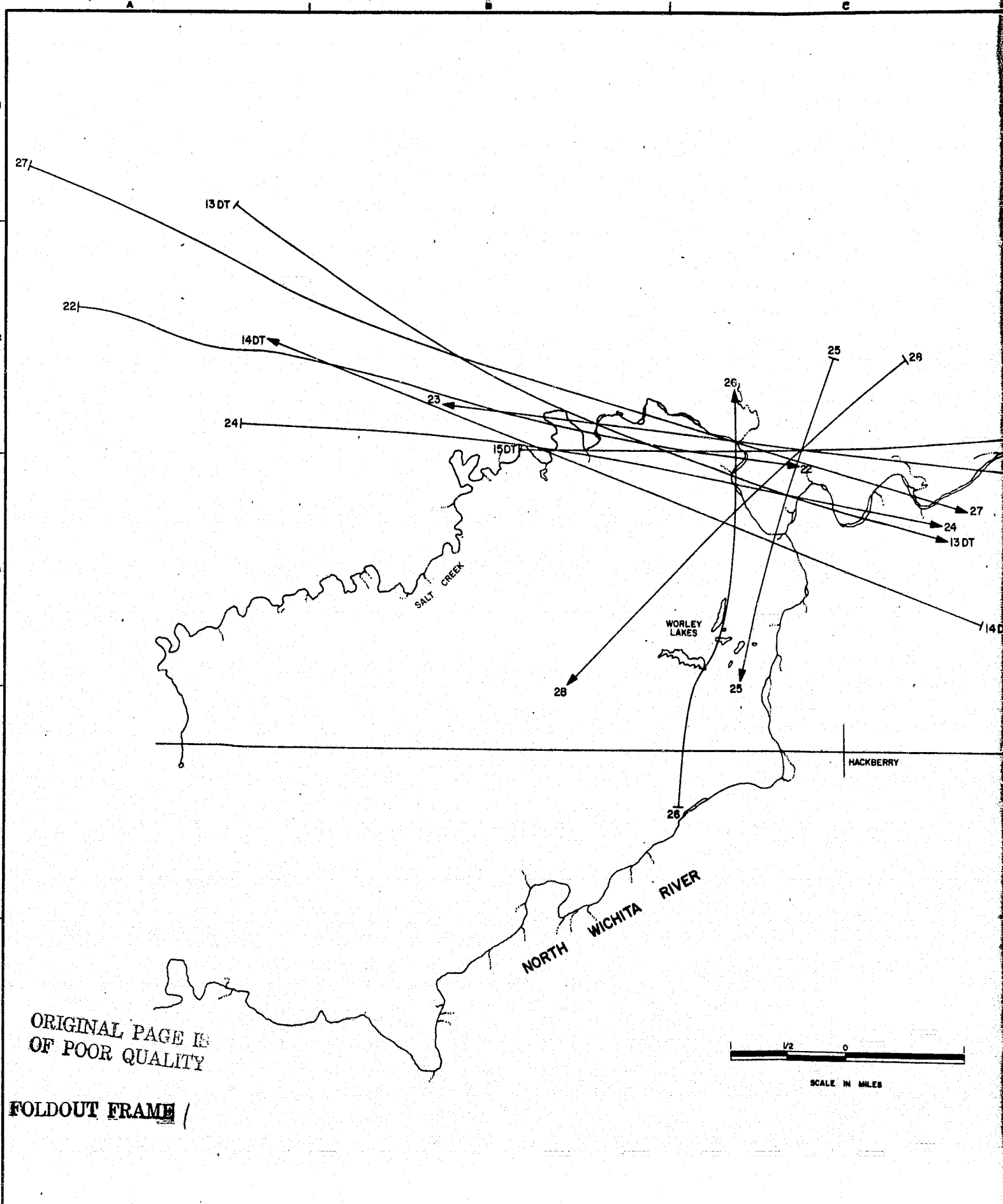
FOLDOUT FRAME /

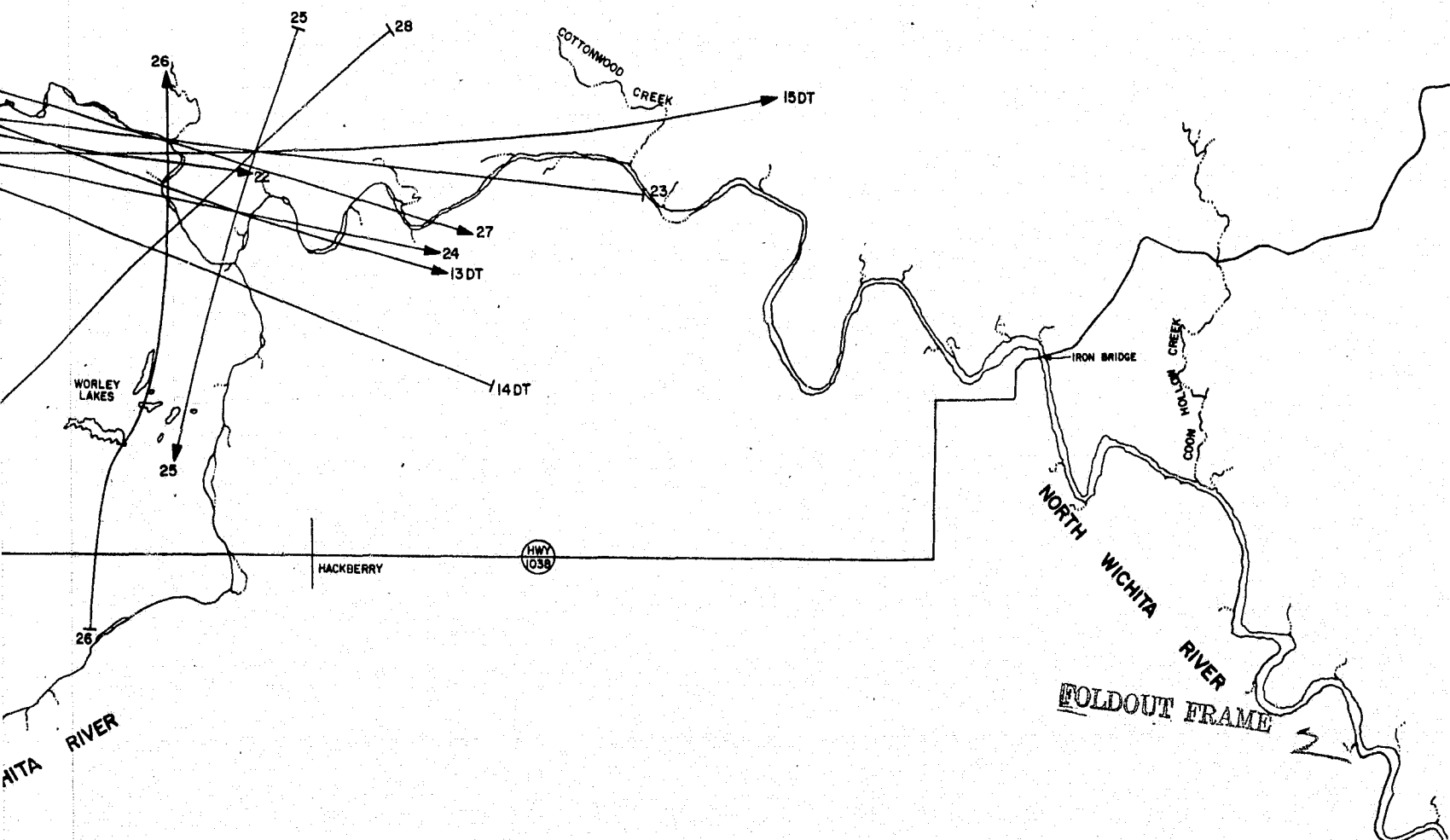


FOLDOUT FRAME



KEY	DATE	CHANGE	REVISION (INDICATED BY Δ)	APPR.
U. S. ARMY ENGINEER DISTRICT, TULSA CORPS OF ENGINEERS TULSA, OKLAHOMA				
DESIGNED BY:		AREAS XIII, XIV, V and PRAIRE DOG TOWN FORK of the RED RIVER IRT FLIGHT LINE PATHS		
DRAWN BY:				
CHECKED BY:				
SUBMITTED:				
CHIEF:		INVITATION NO. DACW38- -D-00 SCALE: AS SHOWN DRAWING NUMBER		
DATE:				





1 1/2 0
SCALE IN MILES

KEY	DATE	CHANGE	REVISION (INDICATED BY Δ)	APPR.
U. S. ARMY ENGINEER DISTRICT, TULSA CORPS OF ENGINEERS TULSA, OKLAHOMA				
DESIGNED BY:		AREA VII IRT FLIGHT LINE PATHS		
DRAWN BY:				
CHECKED BY:				
SUBMITTED:		INVITATION NO. DACWBS- -B-00		
CHIEF,		SCALE: AS SHOWN		
DATE:		DRAWING NUMBER		

MISSION CENTER - SALT SUMP

Area IX - Middle Pease River
Cottle County, Texas



ORIGINAL PAGE IS
OF POOR QUALITY

MISSION CENTER - SALT SUMP

AREA IX - Middle Pease River

Cottle County, Texas

Aluminum Test Panel

Charcoal fire pot

LEGEND

- Brine emission (probable)
- Brine emission (suspected)
- Outflow from emission area,
with increase due to added
emission.

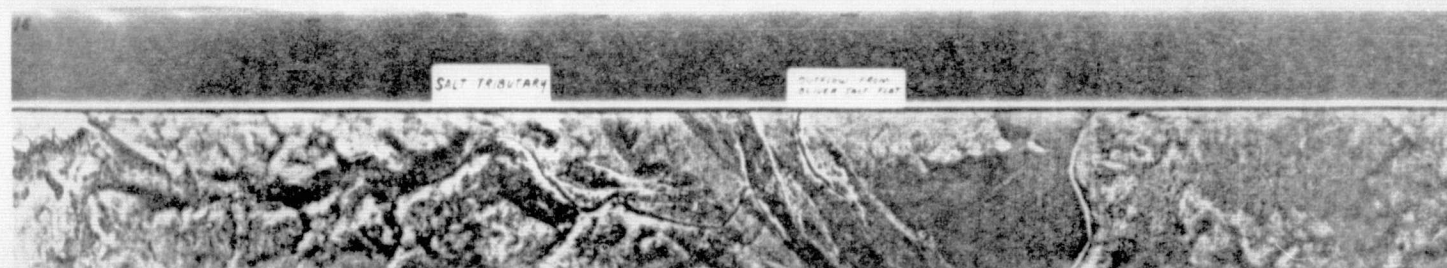
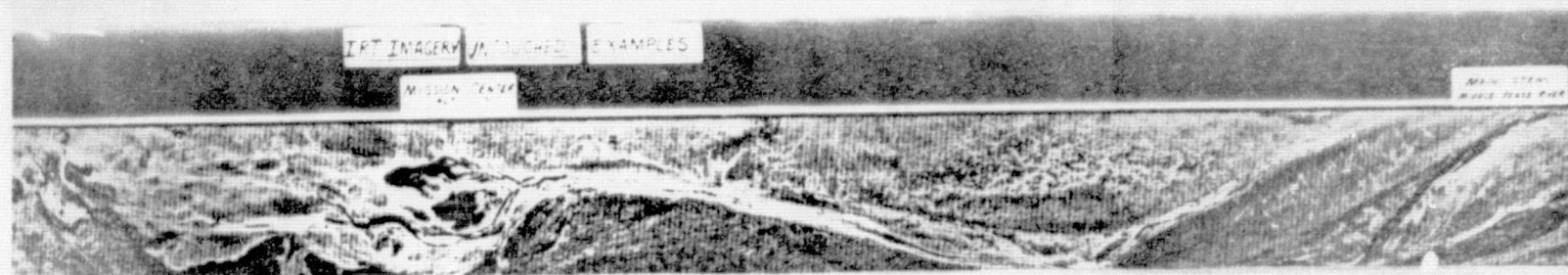
Salt flats, primarily
encrustation or adjacent
affected areas.

- NOTE:
1. Dark tones represent
cool temperatures.
 2. Light tones represent
warm temperatures.

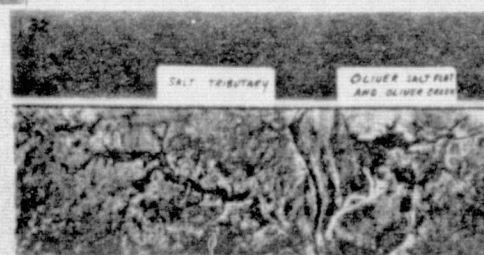
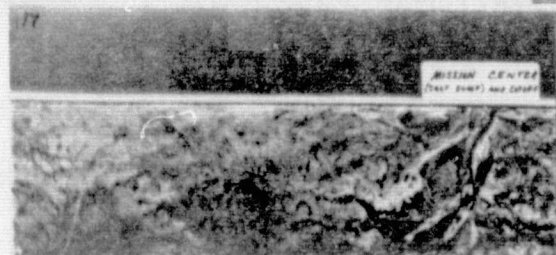
Aluminum test panel



ORIGINAL PAGE 1
OF POOR QUALITY



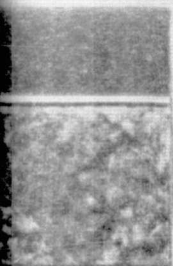
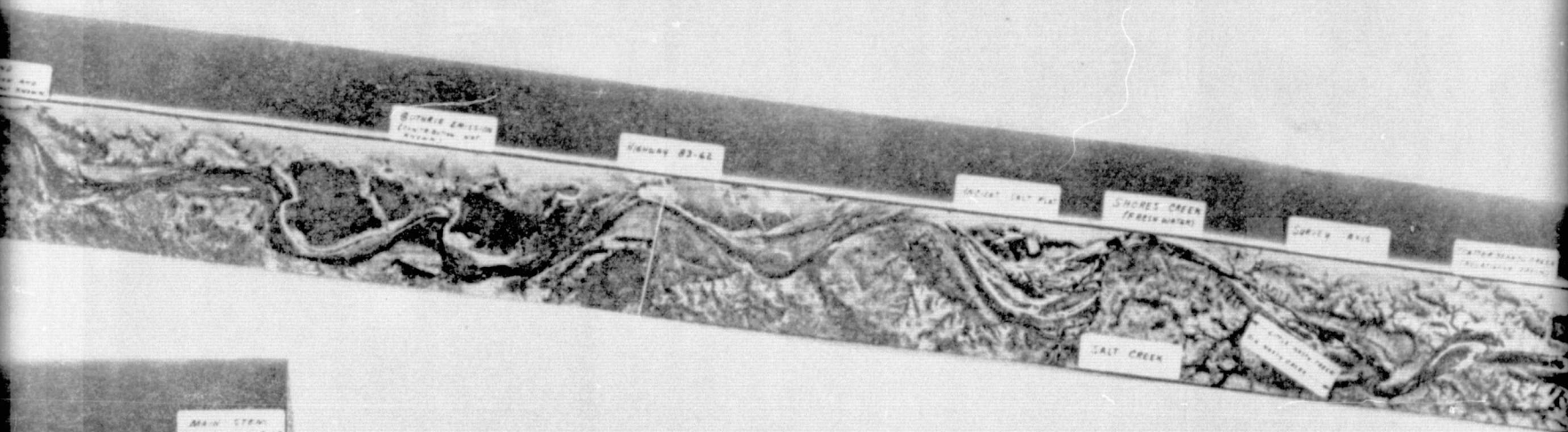
OVERVIEWS



- BRINS E
BRINS E
OUTFLOW F
CARRY IN
SAY FLAY
APPLANT T
C TAMS E
ONLY DACT
STRESS
NOTE
1) 10
2) 10
3) 10
4) 10

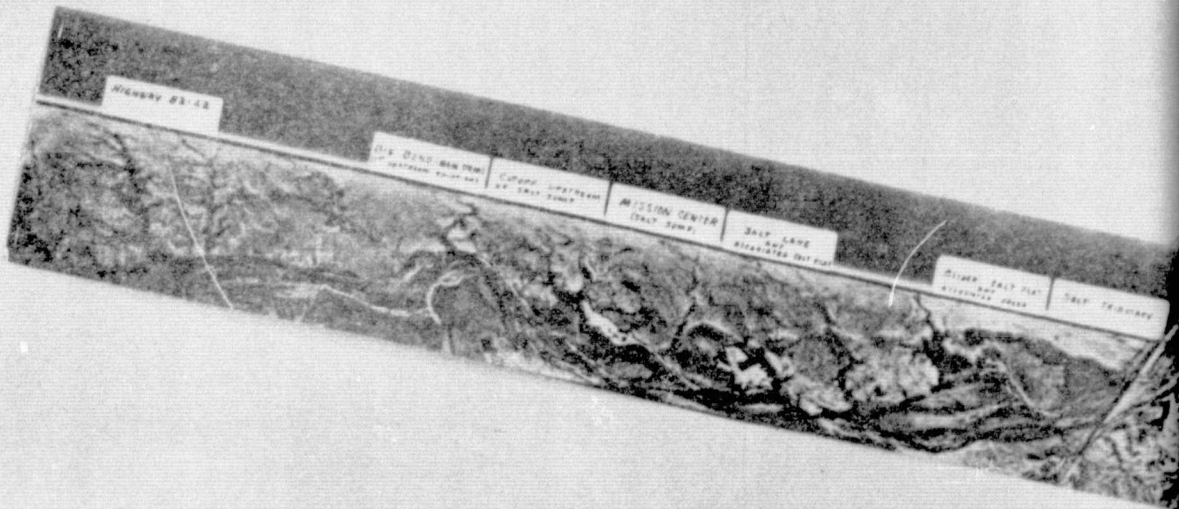
FOLDOUT FRAME

2

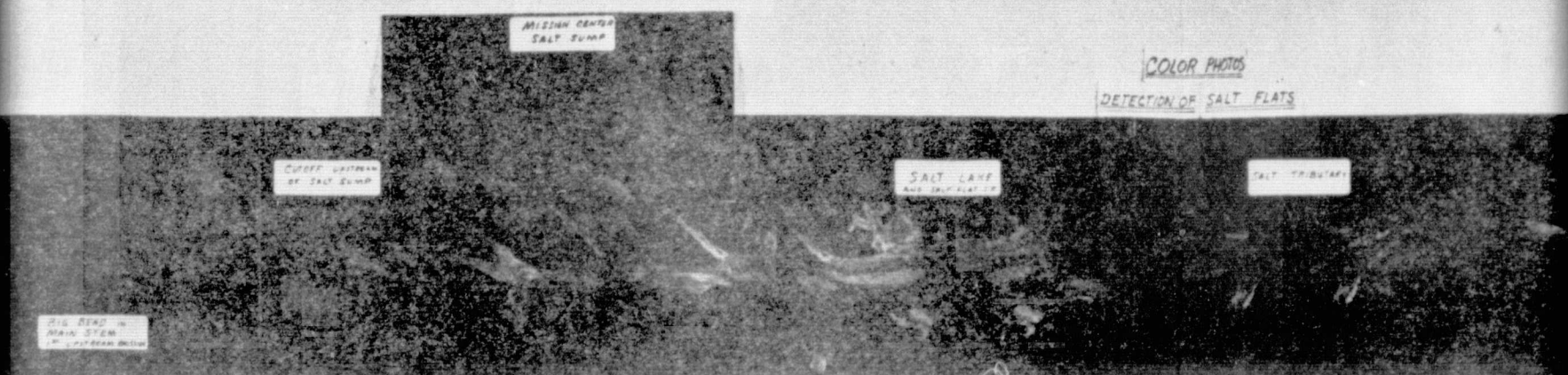


TRT IMAGERY
DETECTION OF SALINE SPRINGS

- LEGEND**
- BRINE EMISSION (PROBABLE)
 - BRINE EMISSION (SUSPECTED)
 - OUTFLOW FROM EMISSION AREA (WITH INCREASE DUE TO ADJACENT EMISSION)
 - SALT FLATS, OR SALT EVAPORATION AREAS (SALT EVAPORATION)
 - ONLY PARTIAL, HAZARD OF FRESH WATER STREAMS
- NOTE**
- (1) SALINE SPRING IN THE MAIN STEM AND THE HAZARD
 - (2) SALT EVAPORATION + SALT FLATS
 - (3) SALT EVAPORATION + SALT FLATS
 - (4) SALT EVAPORATION + SALT FLATS

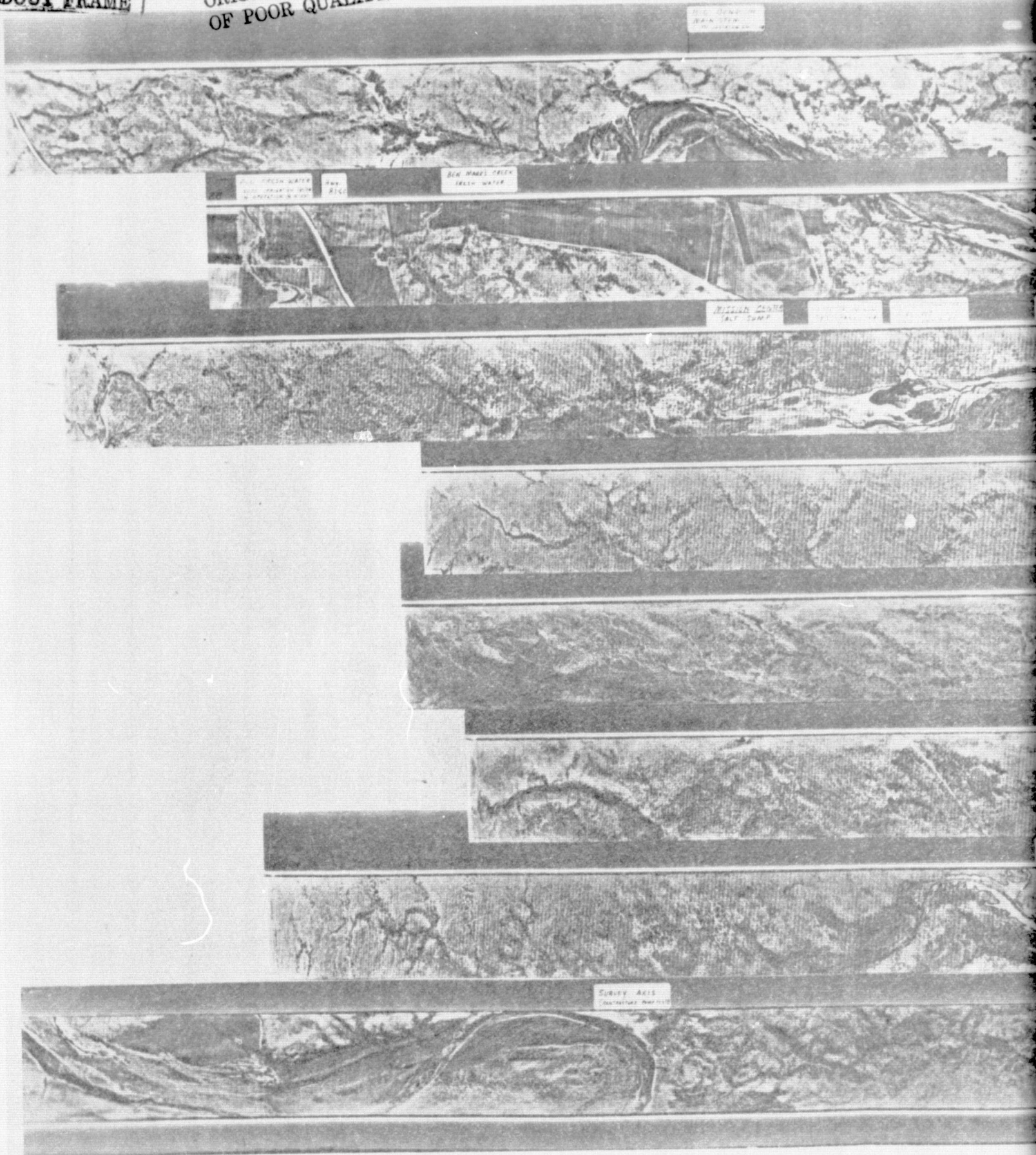


COLOR PHOTOS
DETECTION OF SALT FLATS



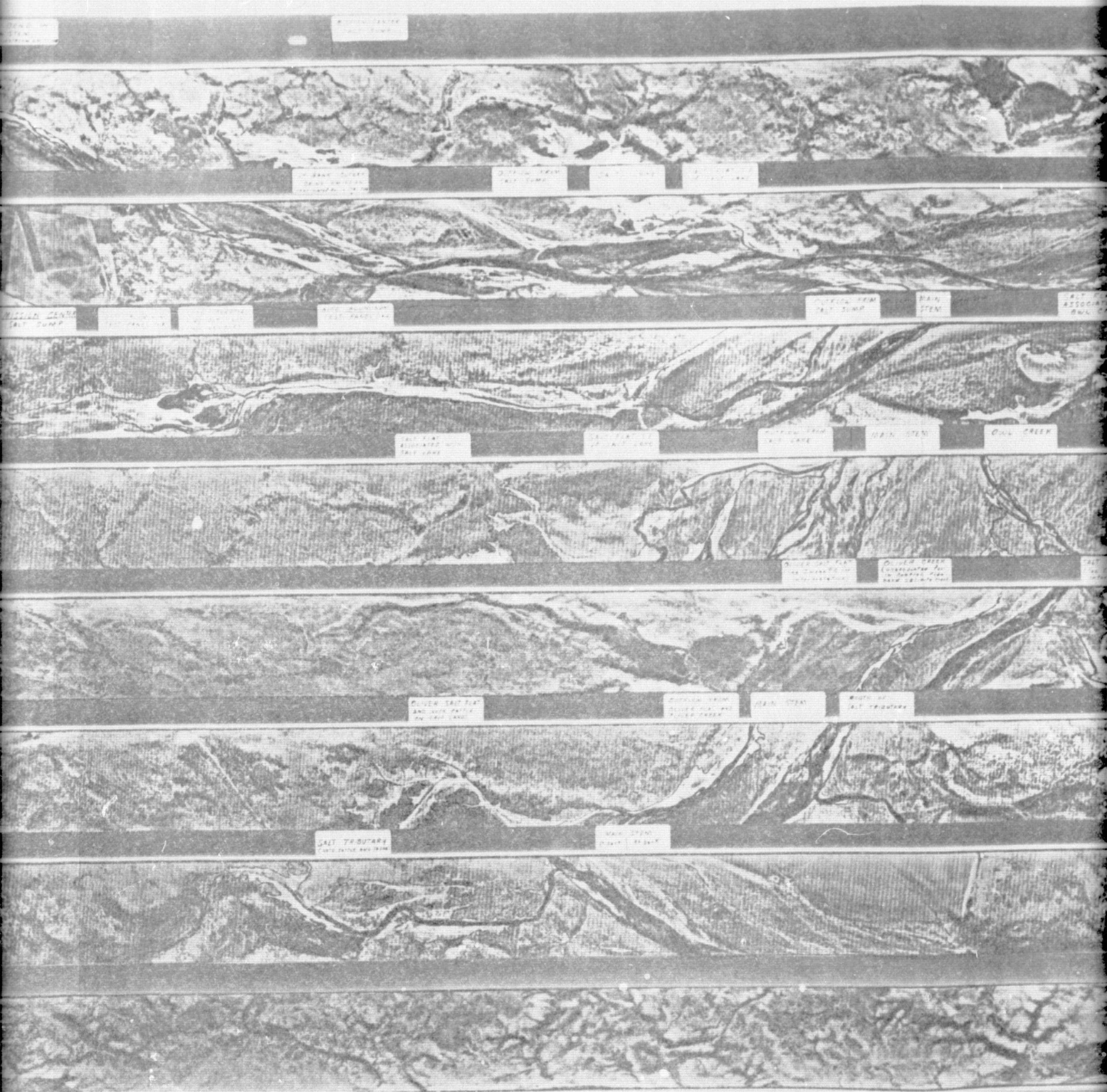
MAIN STEM (SUSPECTED)

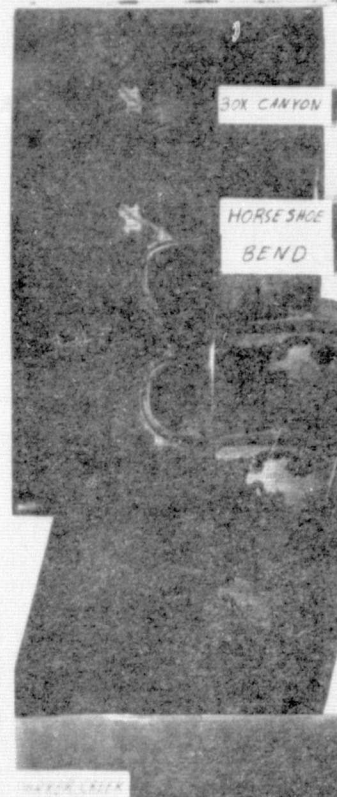
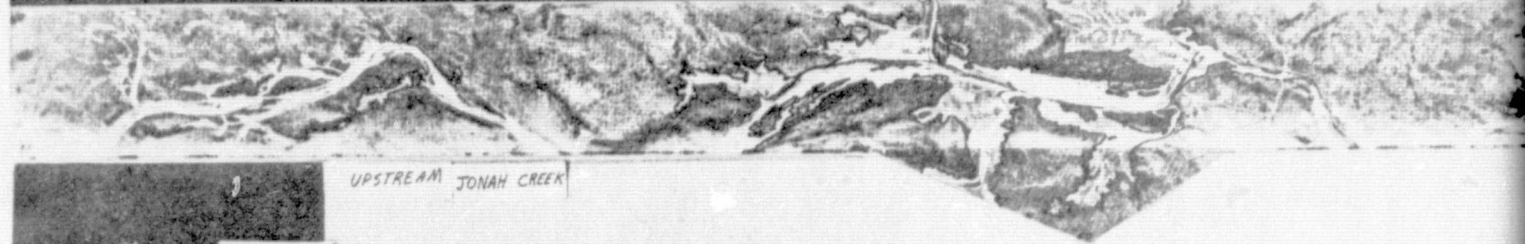
ORIGINAL PAGE IS
OF POOR QUALITY



FOLDOUT FRAME

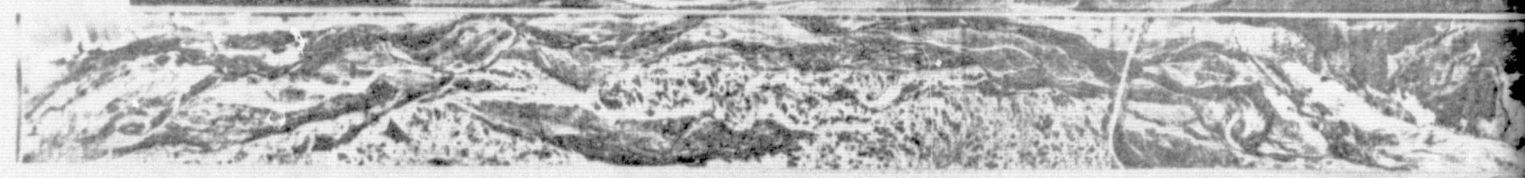
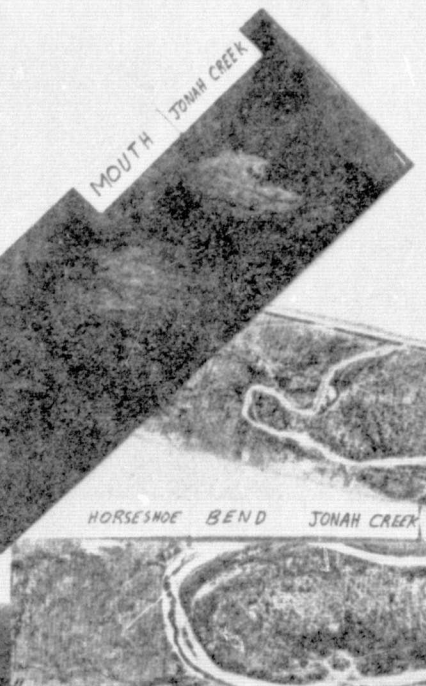
五





UPSTREAM JONAH CREEK

JONAH CREEK CROSSING



ESTELLINE SPRING →

AREA V

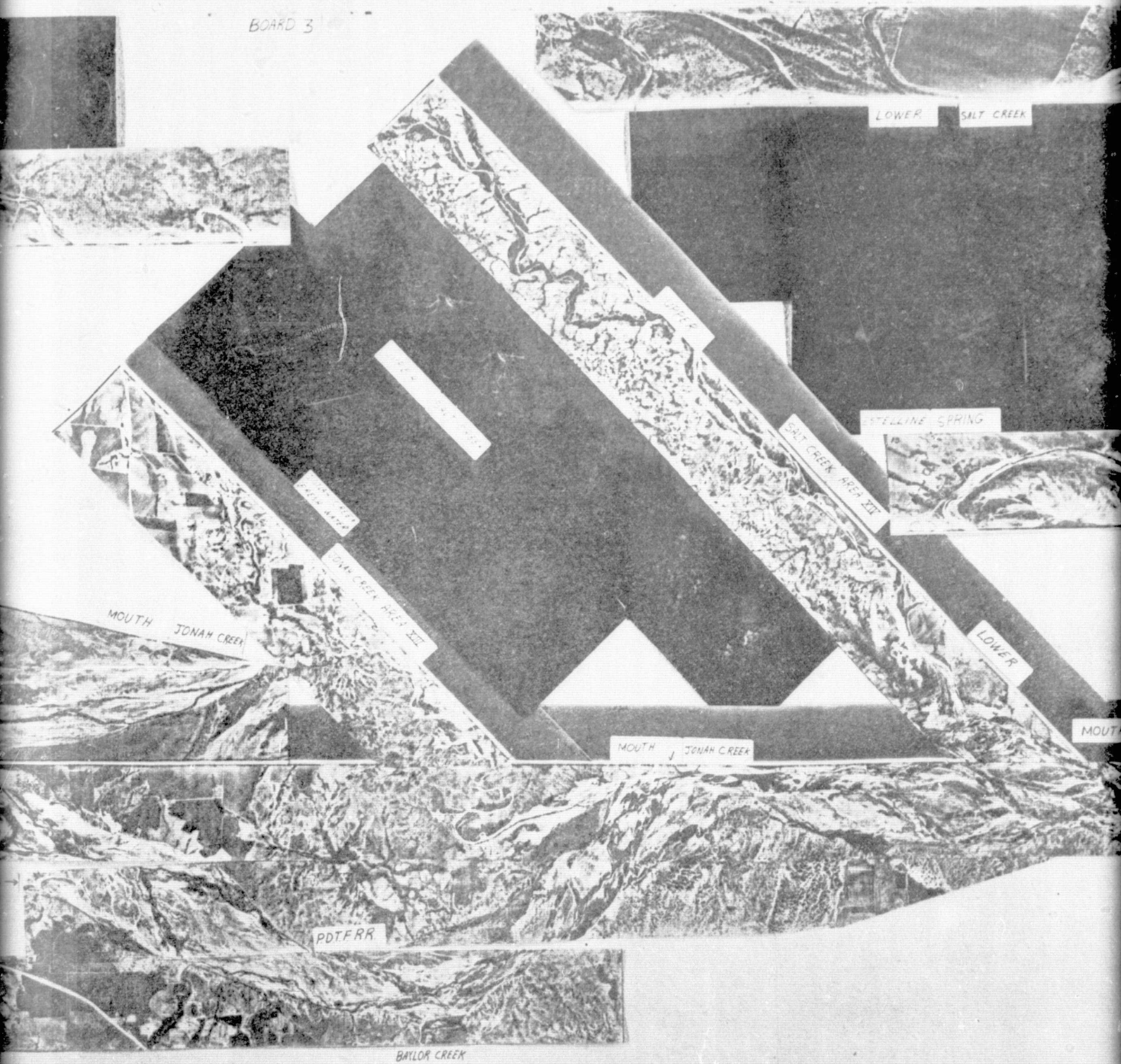
HIGHWAY 287

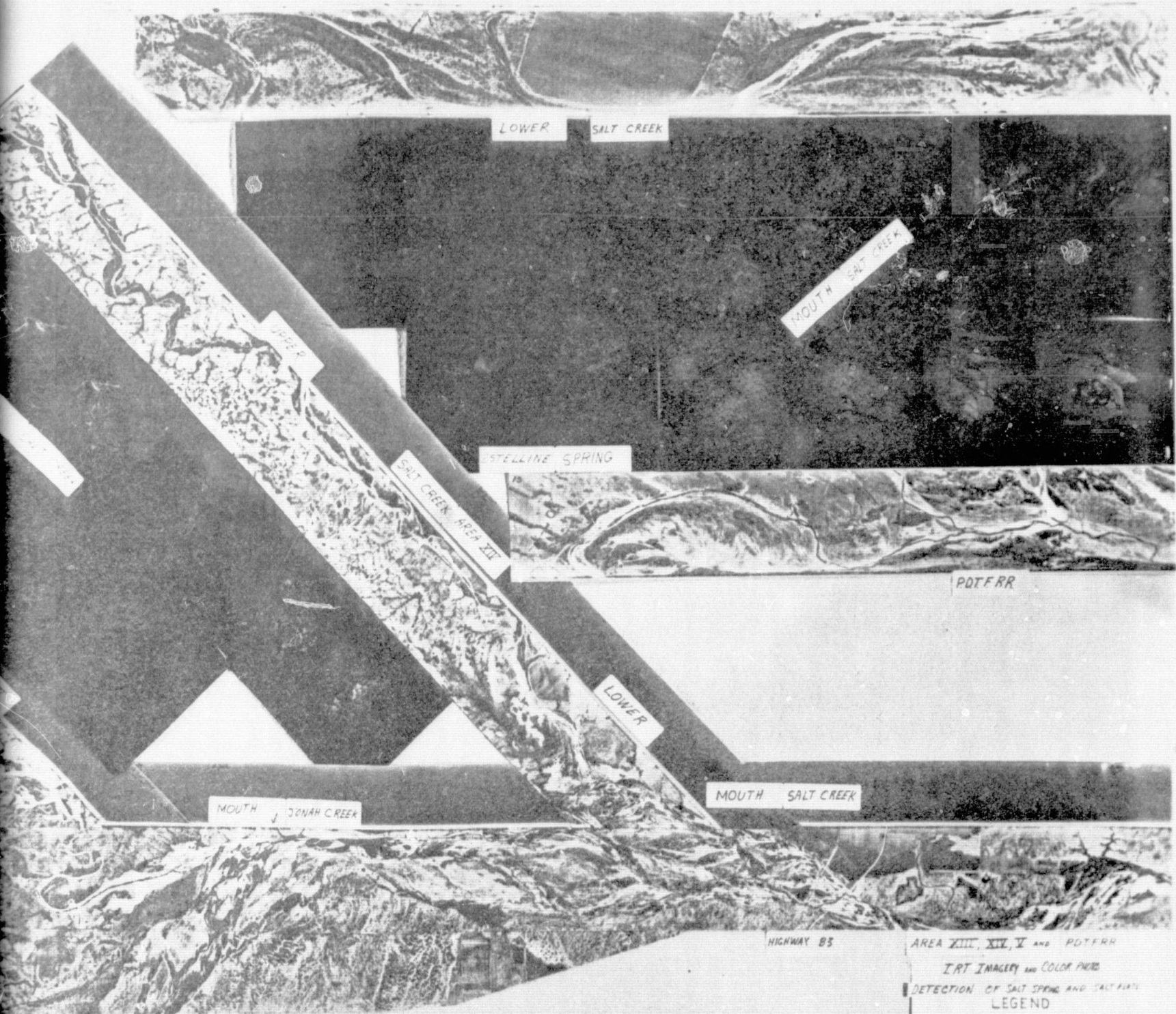


ORIGINAL PAGE IS
OF POOR QUALITY

FOLDOUT FRAME

BOARD 3





AREA XIII, XII, I and POTERR
 IRT IMAGERY and COLOR PHOTO
 DETECTION OF SALT SPRING AND SALT FLATS
 LEGEND

- BRINE EMISSION (PROBABLE)
- BRINE EMISSION (SUSPECTED)
- OUTFLOW FROM EMULSION AREA
 (WATER INCREASED DUE TO SEASONAL CHANGES)
- SALT FLATS, AS SHOWN BY REFLECTED LIGHT
 (SALT FLATS ARE NOT DETECTED BY IRT)
- ONLY FRESHWATER HARBORS IN FRESH WATER SYSTEMS

NOTE:
 (1) COLOR PHOTO IN THE RIGHT HAND
 (2) SALT TEMPERATURE - 100°F
 (3) SALT TEMPERATURE - 100°F
 (4) SALT TEMPERATURE - 100°F

EOLDOUT FRAME 3



LINE 6
250-259

LINE 15
250-255

LINE 16
242-256

LINE 13
221-235

LINE 12
166-180

LINE 11
147-158

FOLDOUT FRAME

ORIGINAL PAGE IS

LINE 11
147-158

LINE 10
80-89

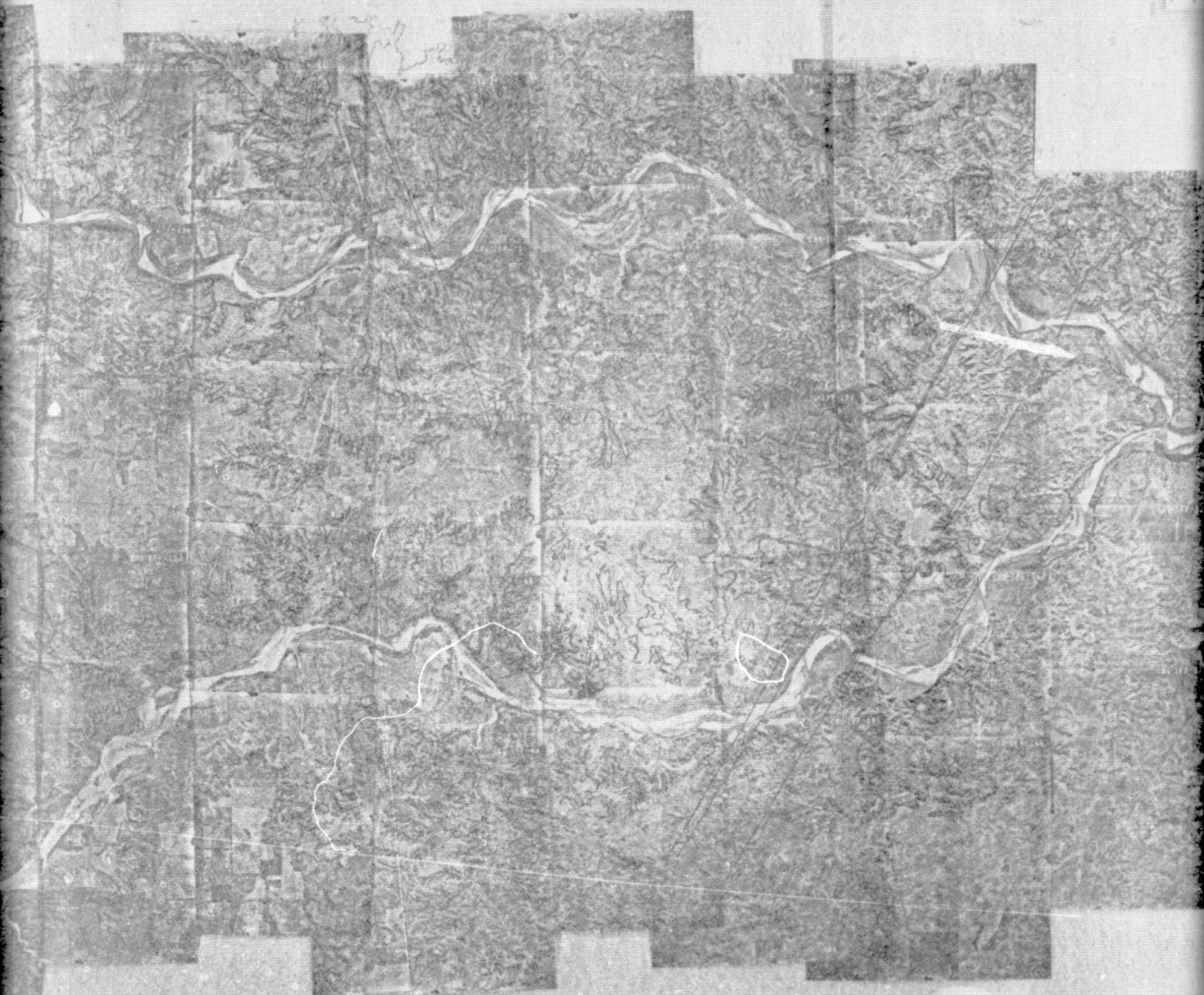
LINE 9
63-73

LINE 8
5-15

LINE 7
194-203

LINE 6
136-144

LINE 5
21-127



SCALE

1 1/2 0 2 MILES

FOLDOUT FRAME

2

LINE 8
5-15

LINE 7
194-203

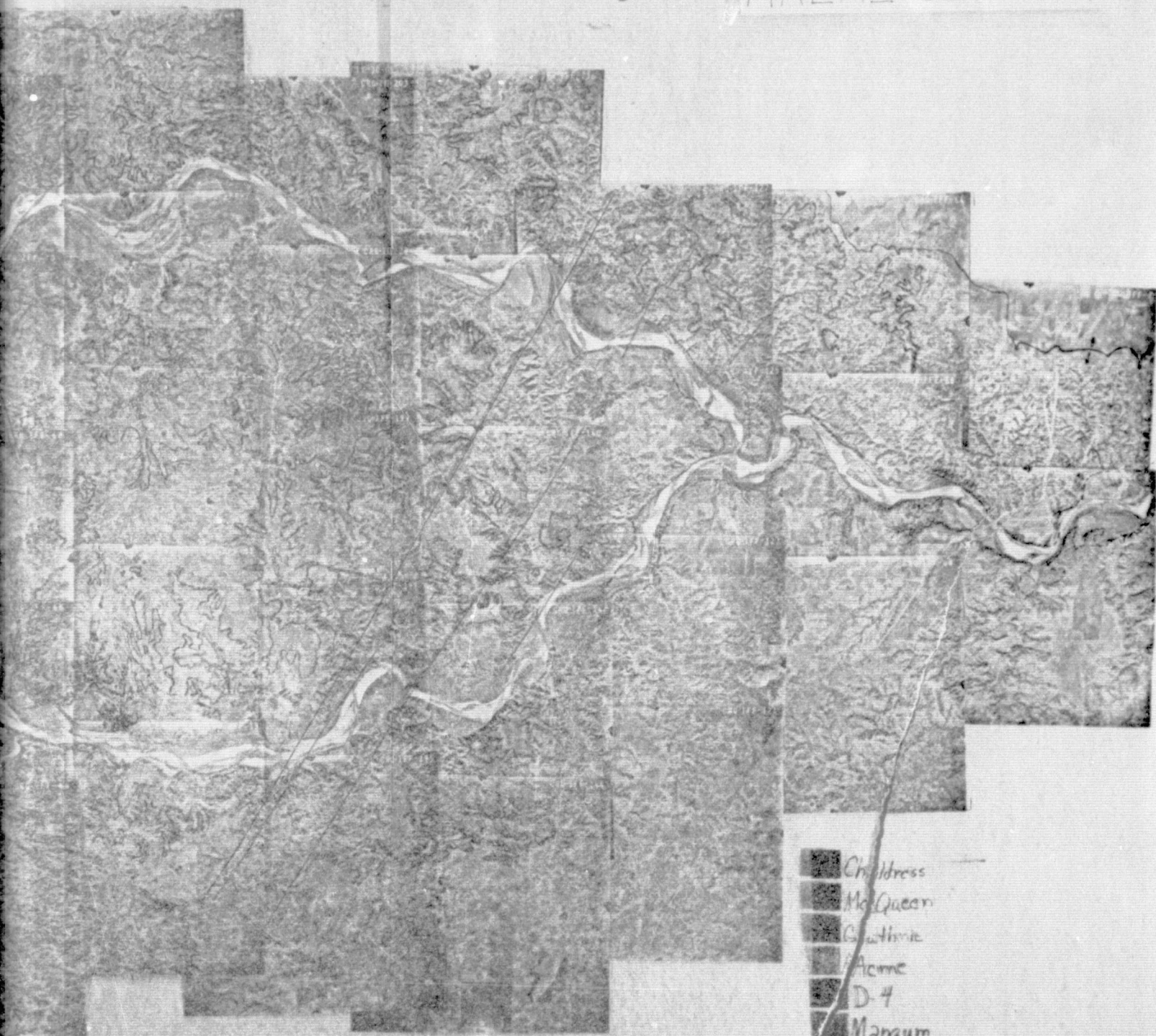
LINE 6
136-144

LINE 5
121-127

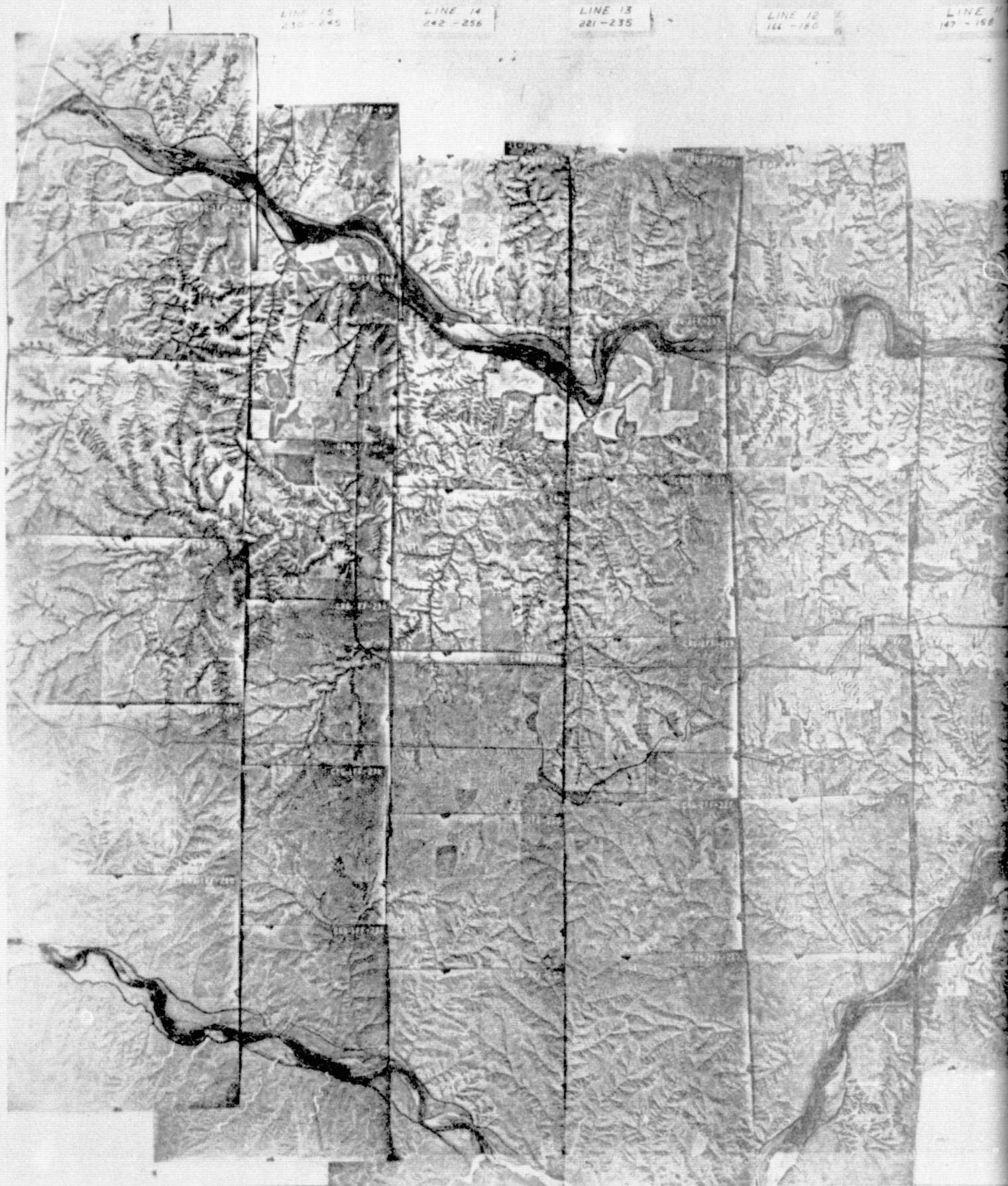
LINE 4
64-67

LINE 3
7-11

AREA IX AREAL GEOLOGY



- Childress
- McQueen
- Gaultine
- Acme
- D-4
- Mangum
- Pleistocene



LINE 15
230-245

LINE 14
242-256

LINE 13
281-235

LINE 12
166-180

LINE 11
147-158

LINE 11
147-158

LINE 10
80-89

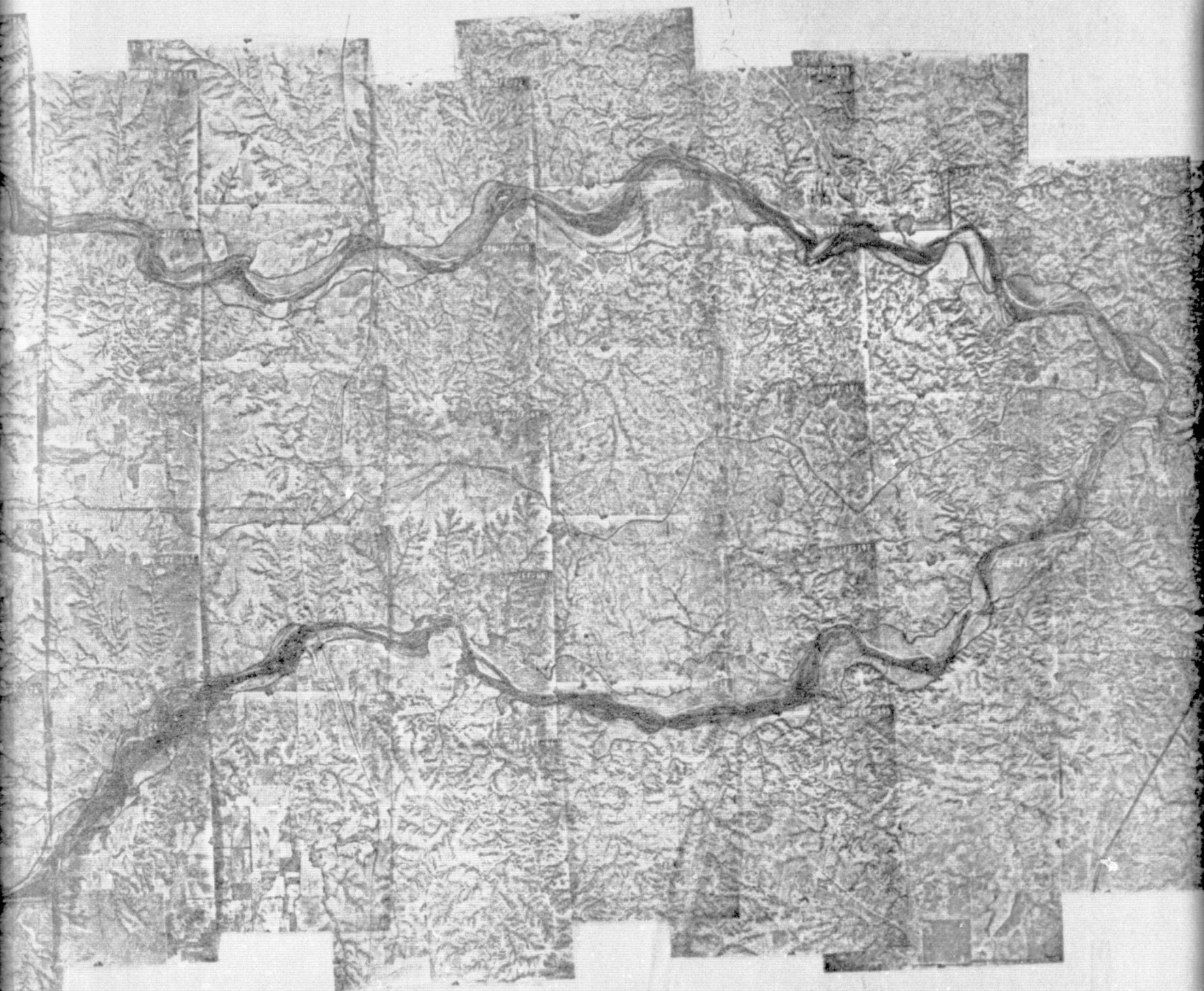
LINE 9
63-73

LINE 8
5-15

LINE 7
194-203

LINE 6
136-144

LINE 5
121-127



SCALE

LINE 9
18-73

LINE 8
5-15

LINE 7
194-203

LINE 6
136-144

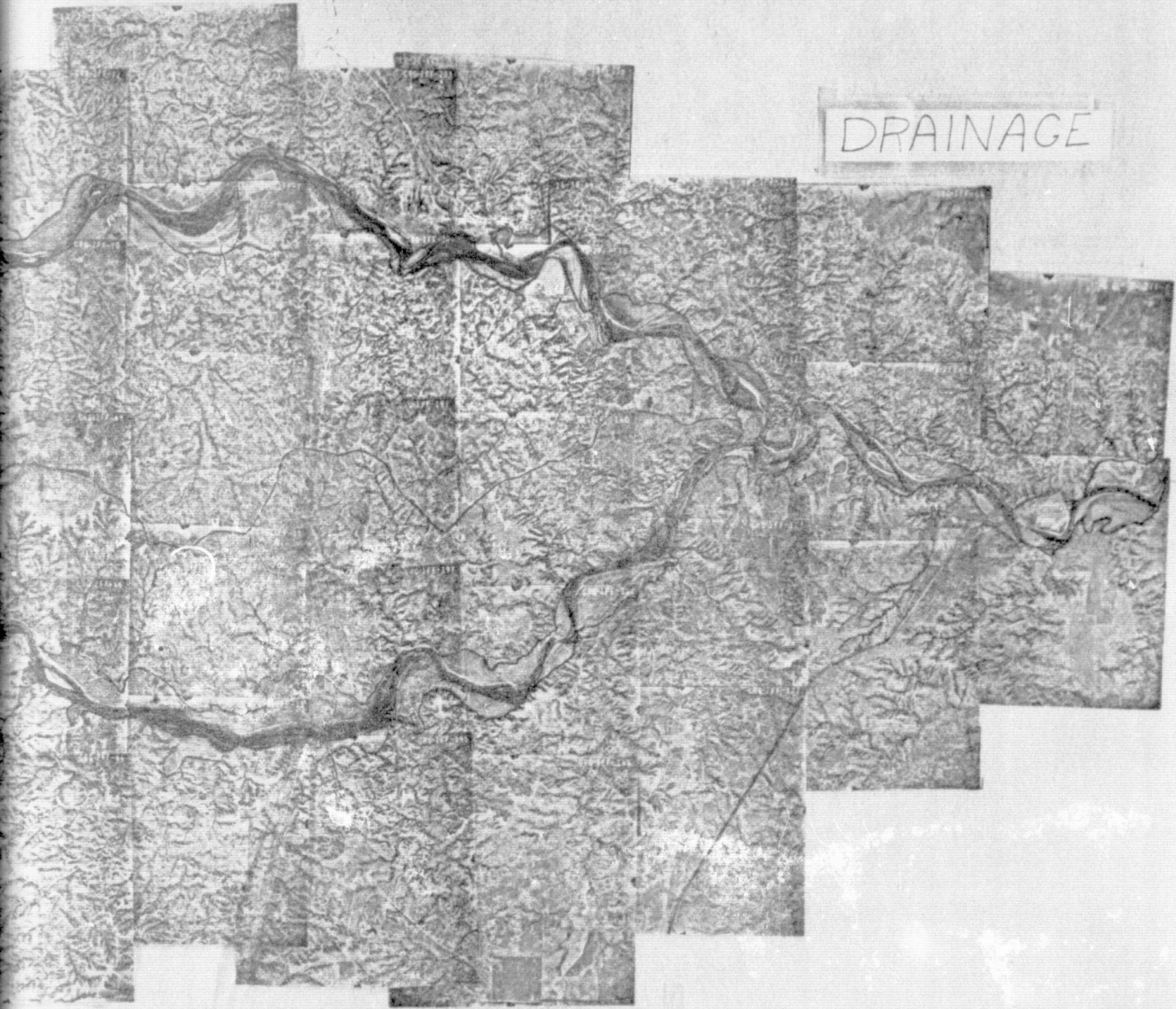
LINE 5
121-127

LINE 4
64-69

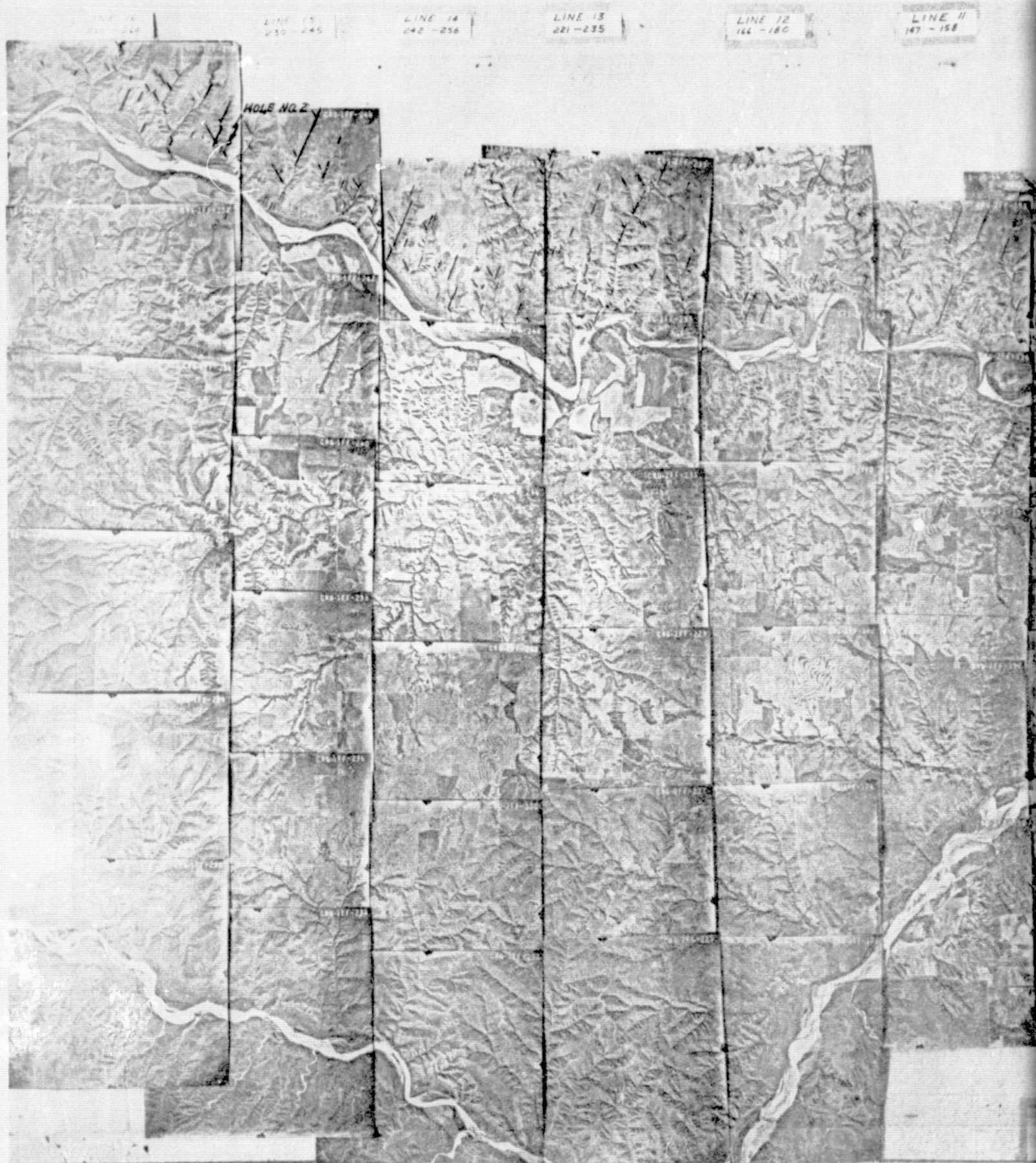
LINE 3
7-11

AREA IX

DRAINAGE



COLDOUT FRAME



FOLDOUT FRAME

ORIGINAL PAGE IS
OF POOR QUALITY

LINE 11
147-158

LINE 10
80-89

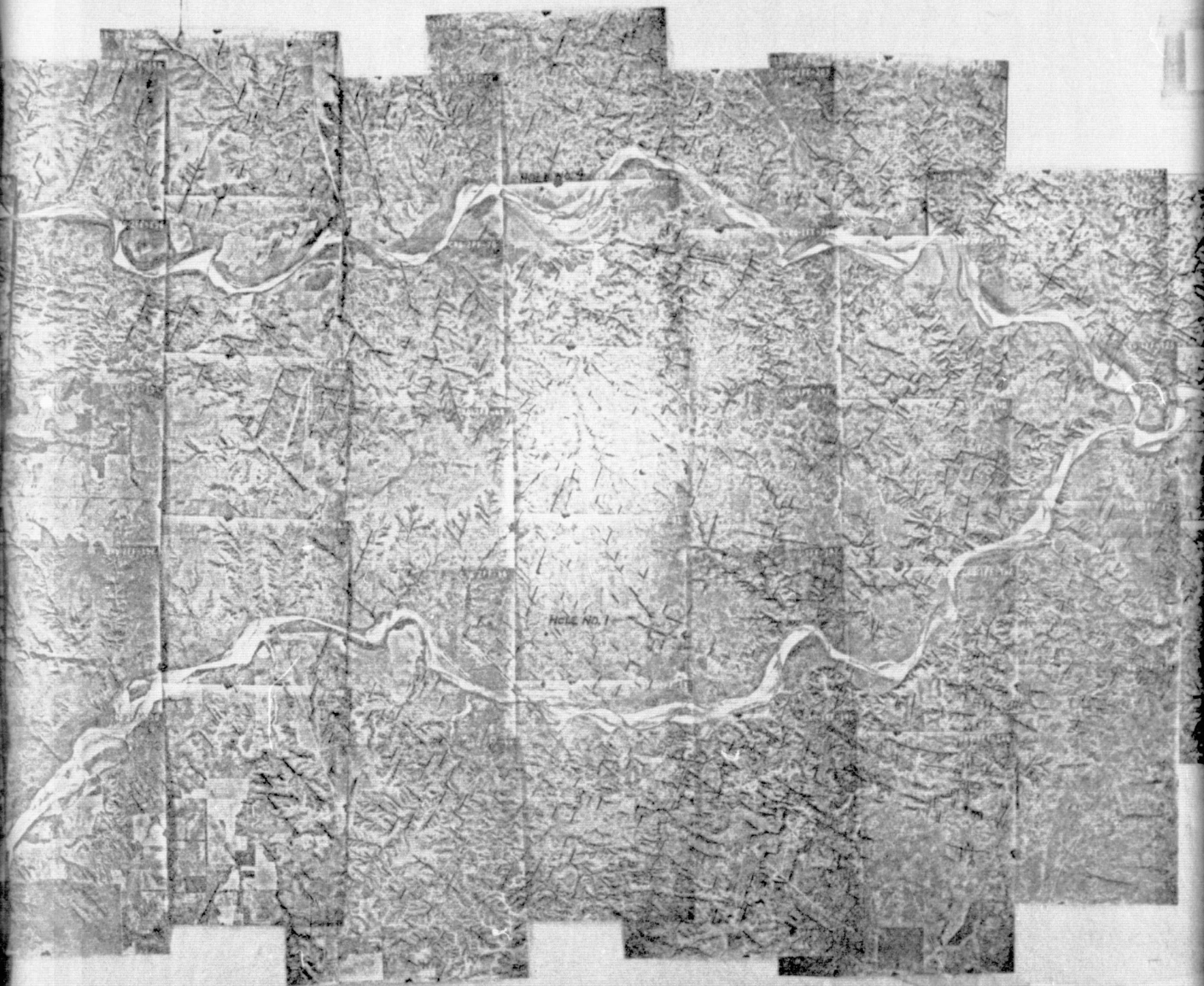
LINE 9
43-73

LINE 8
5-15

LINE 7
194-203

LINE 6
136-144

LINE 5
21-127



SCALE

1 1/2 0 2 MILES

COLDOUT FRAME 2

LINE 8
5-15

LINE 7
194-203

LINE 6
156-144

LINE 5
21-27

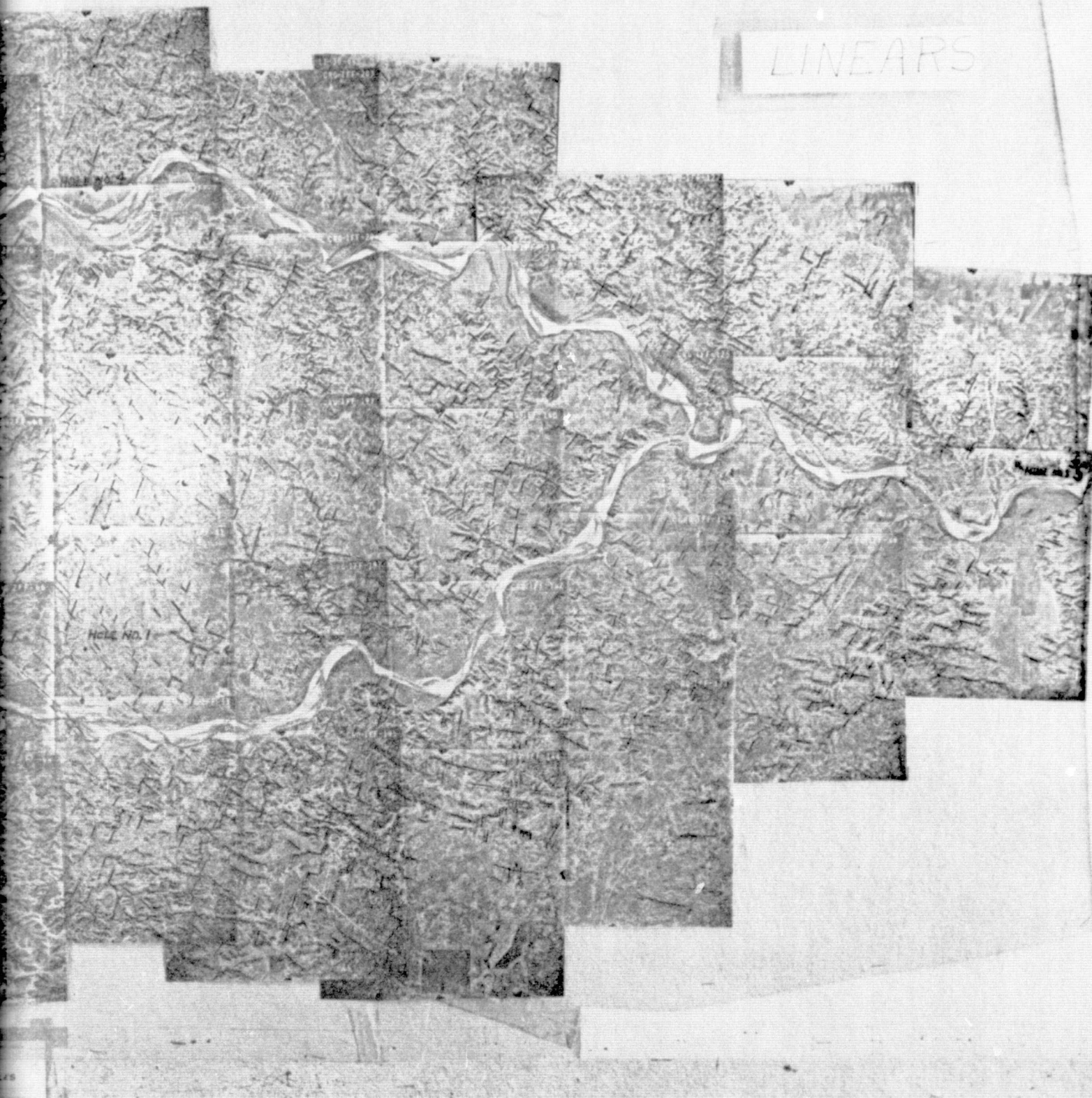
LINE 4
44-49

LINE 3
7-11

BOARD 4

AREA IX

LINEARS



FOLDOUT FRAME